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SATELLITE DATA DERIVED ESTIMATES OF EROSION PARAMETERS FOR REENTRY VEHICLES

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5 February 1991

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February 1990-November 1990

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GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
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13. ABSTRACT *(Maximum 200 words)*

This pilot study investigates derivation of reentry vehicle erosion parameter estimates based on the inference of rain rate and hydrometeor liquid water content from microwave imagery data from the Defense Meteorological Satellite Program (DMSP) sensors. Specifically, this research focuses on the evaluation of Special Sensor Microwave/Imager (SSM/I) brightness temperature data to obtain a climatology of intense precipitation at selected relevant land based sites for a four month summer period. An integral element of the study is the identification of convective cloud models to support the analysis of hydrometeor liquid water content from the inferred surface rainfall rates.

The study consisted of four tasks: (1) development of SSM/I rain rate climatology, (2) development of hydrometeor liquid water content parameterization, (3) application of liquid water parameterization, and (4) documentation.

Software was implemented to (a) read the SSM/I TDRs from the acquired SSM/I data tapes, (b) calibrate and antenna pattern correct the data to obtain brightness temperatures, (c) bin the data according to the location of each desired site by latitude and longitude, (d) apply the rain rate retrieval algorithm to the data, and (e) evaluate relevant climatologies. The latter included four month summer time series of average rainfall rate, spatial standard deviation, and hydrometeor integrated liquid water content for eleven Eurasian sites.

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1. INTRODUCTION

Reentry vehicle erosion is an adverse environmental impact on weapons delivery systems with potential significance. This phenomenon which directly affects the accuracy of reentry trajectories is attributable to mechanical ablation of vehicle aerodynamic surfaces during reentry due to interaction with atmospheric ice clouds and solid or liquid hydrometeors (i.e. precipitation). Assessment of existing or prediction of future erosion severity potential requires an understanding of the temporal and spatial distribution (i.e. climatology) of contributing meteorological conditions. These include both high altitude cirrus cloud and convective activity at lower altitudes. Thus, appropriate analyses and observation techniques are necessary to characterize cloud and hydrometeors. This report focuses on the latter issue. In particular, due to the site specific nature of the erosion problem, analyses are required at specific land based locations.

Significant effort has been devoted to the development of analysis techniques based on time/altitude cross section analyses to identify regions of likely convective activity (Feteris et al., 1976; Hardy, 1979). These approaches supported by radiosonde and surface station data were labor intensive and subject to the sparcity of available surface and upper air data. For the latter reason, for example, questions of spatial representativeness are always present (Bunting and Touart, 1980). Due to the level of effort involved in implementing these approaches, they are unsuitable for application to large scale climatological studies.

Both cloud and hydrometeors can be observed globally using satellite based sensors (Isaacs et al., 1986). Previous application of visible and infrared satellite imagery data to the cloud problem is discussed by Conover and Bunting (1977). The advent of remotely sensed microwave imagery such as that from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) provides the capability to directly sense hydrometeor liquid water content (Savage et al., 1987). Due to the radiative transfer physics relevant to the remote sensing of precipitation, the phenomenology of rain rate retrieval is different over land and oceans. This is due to the inherent differences in land type and ocean surface emissivities (Isaacs et al., 1989). Retrieval techniques have been identified to provide quantitative measurements of rainfall rates over the ocean based on microwave imager data (Wilheit et al., 1977) and oceanic climatologies have been developed (NASA, 1976).

Due to the spatial variation of emissivities over land and temporal features such as snow (which have signatures similar to precipitation), there are caveats related to the retrieval of rain rate over land. However, in optically thick situations when surface contributions to measured brightness temperatures are small, precipitation can be inferred. Such optically thick cases are those which characterize intense convection and these can be mapped over land (Spencer and Santek, 1985). The recently completed SSM/I calibration/validation study provides further confidence in the validity of seeking quantitative inferences of rain rate over both ocean and land. The specific analysis tool available in this regard is the rate rate retrieval algorithm developed by the University of Wisconsin research group (Olson et al., 1988).

While rainfall rate brightness temperature relationships have been validated based on the MJCS 154-86 requirements for precipitation measurements, the physics of the reentry erosion phenomenon indicates that a knowledge of the liquid water content profile is necessary. This can be achieved by adoption of a suitable model of the vertical distribution of liquid water content resulting in the desired surface rainfall rate. The selection of the meteorologically appropriate liquid water content vertical distribution model is important due to the relationship between liquid water content and radiometric signature through the dropsize distribution (Falcone et al., 1979). For example, many investigators commonly use the Marshall Palmer (1948) relationship which was derived for stratiform rain. Erosion severity is a function of precipitation severity and, therefore, convective situations are of greater potential interest. For these cases, other relationships are likely valid (Ulbrich, 1983; Willis and Tattleman, 1989).

This research study applies SSM/I based precipitation remote sensing technology to the characterization of reentry vehicle erosion environments over selected sites. Three complementary areas of investigation were identified in our study proposal: (a) data acquisition and application of the SSM/I rain rate retrieval algorithm to the development of a four month summer climatology of rain rate over selected sites with an emphasis on the identification and analysis of heavy rain rate situations, (b) identification and assessment of appropriate convective cloud models to establish a parameterization of the relationship between surface rainfall rate and the vertical profile of hydrometeor liquid water content, and (c) testing of the parameterization of hydrometeor liquid water content on the determination of liquid water content profiles for selected cases with emphasis on intense convection. These issues are explored in the following sections.

2. BACKGROUND

2.1 Rain Rate Retrieval Concepts

At microwave wavelengths, precipitation sized droplets provide a source of atmospheric attenuation analogous to the effect of cloud droplets in the infrared spectrum (Savage, 1978; Falcone et al., 1979). This attenuation mechanism suggests a direct causal relationship between rainfall and microwave atmospheric emission which has been exploited to infer rainfall rate (Weinman and Wilheit, 1981). Furthermore, the presence of precipitation within the field of view of microwave sensors is itself of considerable interest since the quality of resultant retrievals of other quantities is most certainly degraded (Liou et al., 1981). For example, microwave sounding brightness temperatures such as those from the SSM/T must be corrected for rain in much the same way as infrared radiances are for cloud. To provide a theoretical microwave brightness temperature/rainfall rate relationship applicable to rain rate retrieval, models of both the rain layer (including a rain layer height and thickness) and of rain microphysics are required. These models determine the vertical distribution of hydrometeor liquid water content. Both of these factors, of course, vary synoptically introducing some uncertainty into the retrieval process.

Collectively, these factors determine the atmosphere's scattering and absorption contribution to total satellite incident brightness temperature which is evaluated as a multiple scattering calculation assuming that the rain layer fills the field of view. Microwave radiative transfer theory accounting for multiple scattering has been extensively applied to the study of atmospheric precipitation and clouds (Weinman and Guetter, 1977; Wilheit et al., 1977; Tsang and Kong, 1977; Jin and Isaacs, 1985). The surface background against which the rain is modeled consists of surface emission and surface reflected atmospheric contributions, which must be included.

Over the ocean, surface emissivity is low and relatively uniform, providing good contrast for the quantification of precipitation. This approach was applied over the ocean by Wilheit et al. (1977) to data from the NIMBUS 5 Electronically Scanning Microwave Spectrometer (ESMR) operating at 19.35 GHz. Accuracies of 2 mm/h and a dynamic range up to about 20 mm/h were achieved using ground based radar for validation. Results based on retrievals obtained using the Seasat and Nimbus 7 SMMR instruments, for example, indicate that the retrieved rainfall rates generally underestimate those measured at the surface with rain gages (cf. Gloerson et al., 1984). Lipes (1982) found that the Seasat SMMR failed to detect showery precipitation associated with convective cloud in midlatitudes and underestimated rain rates for heavy precipitation. This behavior was attributed to both loss of incremental sensitivity to precipitation at higher rainfall rates and insufficient sensor resolution (about 30 km at 37 GHz) in convective situations. Sensor resolution plays a role since intense precipitating cells with horizontal scales of a few kilometers will not fill the microwave radiometer's field of view. Similar results were obtained in midlatitudes by Alishouse (1983).

Theoretical calculations suggest that over land, higher frequency, dual polarized measurements can distinguish atmospheric scattering due to rain from surface contributions (Savage and Weinman, 1975; Weinman and Guetter, 1977; Huang and Liou, 1983).

However, in practice the dynamic range of measurable rainfall rates is so much reduced at 37 GHz that these measurements are virtually useless and considerable ambiguity of surface and atmospheric contributions still exists. In addition to the problems of specifying appropriate rain models and obtaining measurements over land, another problem arises because the typical horizontal scale of precipitating cloud elements is generally much less than the field of view of the ESMR instrument (50 km). Integration over a large field of view creates a negative bias which underestimates instantaneous rainfall rates. In spite of these difficulties, areas of intense precipitation can be identified (Spencer and Santek, 1985). Based upon the above discussion, there will be some difficulties in providing accurate rain rates in intense convective situations from microwave data alone. The rainfall rates in the higher ranges of the desired domain will almost always be due to energetic convective cells with spatial scales on the order of a few kilometers which cannot be fully resolved with the 25 km FOVs of the SSM/I instrument. In such cases it has been noted that high rain rates are always associated with minima in the equivalent blackbody temperature (EBBT) field observed from infrared imagers (Negri and Adler, 1987a,b). The converse of this is not true, however, i.e, low EBBTs can be due to other than precipitation, therefore, it is advantageous to exploit both microwave (for lower rain rates and to identify the presence of intense convective precipitation) and infrared (at higher rain rates) data. At the higher rain rates (and to help in the determination of beam filling at lower rates), OLS infrared imager data can be used. The specific approach adopted could be based on that described by Adler and Negri, 1988. They used GOES imager data to delineate convective rain areas by searching for minima in the EBBT field and then assigned rain rates based on the results from a one dimensional cloud model which provided the relationship between convective development (cloud top height) and the resulting rain rate. Stratiform rain rates were delineated based on EBBT threshold criteria. Due to level of effort constraints, however, this study will focus on the use of SSM/I data alone to derive convective rainfall climatology.

2.2 SSM/I Data Characteristics

The Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I), launched on 19 June 1987, is a passive microwave radiometer which provides brightness temperature data of particular relevance to the monitoring of global precipitation properties. The SSM/I sensor antenna observes seven microwave channels (three dual polarized frequencies: 19.35, 37.0, and 85.5 GHz and a vertically polarized channel at 22.235 GHz) and scans conically with an angle of incidence on the surface of the earth of 53.1 degrees (Savage et al., 1987). Using a single antenna to span this frequency range results in a sensor field-of-view (FOV) which varies with frequency: about 50 km at the two lowest frequencies, 25 km at 37 GHz, and 13 km at 85.5 GHz.

The exact spatial resolution of each FOV depends on the definition used and the antenna response pattern. Based on the polar orbiting DMSP satellite, SSM/I data potentially provides global coverage daily, with twice daily coverage possible at northern latitudes due to orbital overlap. SSM/I data are archived through the DoD-NOAA Shared Metsat Processing agreement by NOAA/ NESDIS through the Cryospheric Data Management System (CDMS) at the National Snow and Ice Data Center (see Weaver et al., 1987). These data consist of both satellite data records (SDRs, i.e. the calibrated brightness temperatures) and environmental d a records (EDRs, i.e. the retrieved parameters). Table 1 illustrates the sensitivity SSM/I microwave imager channels to a variety of desired geophysical parameters (the DMSP assigned priorities for these parameters are in brackets).

The retrieval of precipitation from SSM/I data follows the statistical method outlined in Lo (1983) and used in simulation for SSM/I data sets in Jin and Isaacs (1987). While simulation retrieval results suggest that the required accuracies of a few mm/h are possible at the lower rain rates a number of important factors are often neglected. These include the degree of beamfilling, the vertical extent of the precipitation, the rain drop size distribution,

Table 1. Microwave Imager Channel Applications

Sensor Parameters				
Frequency (GHz)	19.35	22.235	37	85.5
Spatial resolution (km)	50	50	25	12.5
Sensitivity (K)	0.6	0.8	0.8	1.0
Geophysical Parameters, [Priority]				
Precipitation (land) [5]	o		•	•
Precipitation (ocean) [5]	•	o	x	x
Snow cover [10]	•		o	x
Sea ice (extent, type) [18]	•		•	•
Sea surface temperature [8]	o	o	x	
Wind speed (ocean) [4]	o	x	x	x
Atmospheric water (total) [3]	•	•	o	
Soil Moisture [9]	o			
Vegetation (e.g. Albedo [1]	x	o	x	x
Cloud Liquid Water [7]	x	x	x	•

Channels which are important for determining each parameter are indicated using the following code: • = Critical; O = Important; x = Helpful.

the temperature profile through the precipitating layer, and the presence of glaciated precipitation which can significantly alter the brightness temperature signature. These factors are often kept constant in simulations whereas they vary in the natural atmosphere. Uncertainties associated with these factors certainly impact the accuracy of rainfall rate determination, and it is perhaps more reasonable to expect that a few broad rainfall rate categories are retrievable from the SSM/I. Retrievals of precipitation (both liquid and glaciated) and surface emissivity from simulated SSM/I data were discussed in a journal article by Jin and Isaacs (1987) which also described a specially developed multiple scattering model which was designed to simulate dual polarized brightness temperatures in the presence of inhomogeneous, nonisothermal distributions of atmospheric precipitation.

The capability to simulate inhomogeneous (i.e, those varying with height) distributions of precipitation is necessary to treat the realistic variation of rain rate with altitude within developing frontal systems and the phase change (from water to ice) occurring in convective situations. In that paper brightness temperature simulations specifically applicable to the SSM/I were shown. Figure 1, for example, illustrates the dependence of simulated dual polarized 85.5 GHz brightness temperature on rain rate and the presence of an upper layer of frozen precipitation. The figure inset illustrates a model of the simulated atmosphere with a 5 km rain layer over the ocean surface and either a 3 km ice layer or another 3 km rain layer above. It can be seen from these results that due to enhanced multiple scattering at this frequency, the brightness temperature is significantly lowered by the ice layer. At lower frequencies such as 19.35 GHz, the ice layer has little or no effect and, therefore, using the multispectral SSM/I data, the phase of the upper levels of precipitation can be identified in the retrieval/analysis procedure in addition to the rain rate. This provides a method to probe the vertical structure of the precipitation.

A significant calibration/validation effort (Olson et al., 1988) has focused on the SSM/I precipitation retrieval algorithm. The resulting investigation provides simple formulae to obtain rainfall rates over ocean and land and addresses the loss of the 85.5V channel data. The latter issue is of significance for the inference of rain rate over land. We propose to employ the most recent land regression coefficients obtained from the University of Wisconsin group. The steps in the retrieval are essentially: (1) antenna pattern correct, (2) apply existing SSM/I precipitation screening logic, and (3) apply

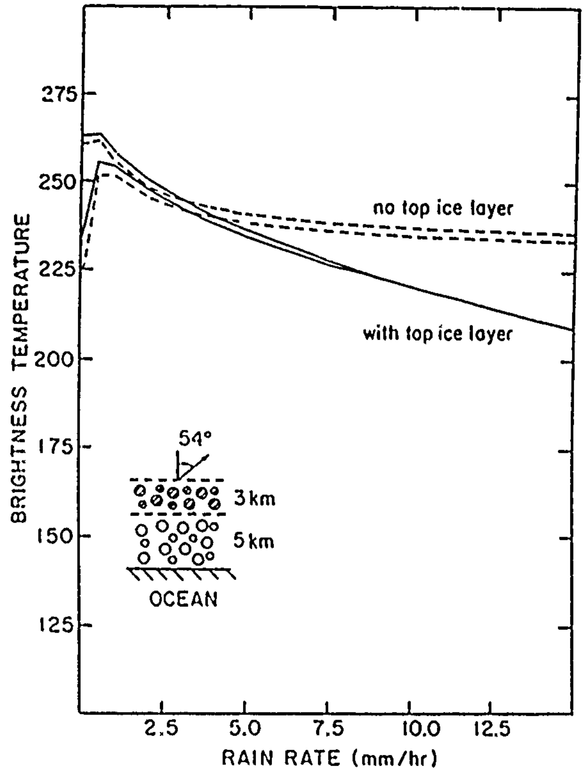

Figure 1. SSM/I dual polarized 85.5 GHz brightness temperature vs. rain rate (mm/hr) with and without top layer of glaciated precipitation

regression formulae for rain rate. Step (1) is part of the coding available with the compacted SSM/I data from Remote Sensing System, Inc. (F. Wentz, personal communication). The coding for steps 2 and 3 will be obtained via GL from the University of Wisconsin. We note that due to the additional computational load imposed by the antenna pattern correction step, it might be prudent to develop a prescreening algorithm to identify precipitating situations directly from the antenna temperatures themselves. If this is possible, only those cases identified need be antenna pattern corrected.

2.3 Convective Cloud Models

As discussed in the previous section, the SSM/I retrieval algorithm provides rain rate as an output parameter although the radiative transfer physics indicates that radiometer brightness temperatures are fundamentally sensitive to hydrometer liquid water content (LWC). Assessment of reentry vehicle erosion indices require determination of a hydrometeor liquid water content vertical profile. The required interface between surface rainfall rate and LWC profile is a model of the vertical distribution of hydrometeors appropriate to the observed synoptic situation. Previous studies such as Peirce et al. (1975) have focused on the applicability of specific hydrometer LWC models for this purpose. Notably, Falcone et al. (1979) have specified climatological cloud and hydrometeor liquid water content models applicable to the simulation of microwave and millimeter wave data sets which provide strawman cloud model candidates as functions of precipitation intensity categories (i.e. light, moderate, heavy). Since the application driven climatological emphasis will be on the delineation of convective precipitation, our focus will be on convective cloud models.

Table 2 provides a list of candidate models which characterize a range of synoptic situations, including: frontal rain, thunderstorms, tropical squall lines, and cumulus towers. For example, a simple one-dimensional convective cloud model is that based on the work of Cotton (1972a,b) and Simpson and Wiggert (1969). The model dynamics are

Table 2. Candidate Convective Cloud Models

Synoptic Situation	*Reference*
Thunderstorm	Helmsfield and Fulton, 1988
Frontal Rainband	Rutledge and Hobbs, 1984
Cumulus Tower	Simpson and Wiggert, 1969
Tropical Squall Line	Tao and Simpson, 1989
Tropical Storm	Wilheit et al., 1982
Convective Cloud	Cotton, 1972a,b

based on the conservation of vertical momentum including the buoyancy effects of perturbation temperature and liquid water loading. Physical processes included in this simple model are the latent heating by condensation, entrainment of environmental air, conversion of cloud liquid water to rain (and its fallout), and the freezing of condensate. The microphysical parameterizations are kept intentionally simple, both in the interests of run time and because of the likely uncertainties in the input data. In Section 5, we discuss the hydrometeor cloud model in greater detail and identify parameterization for stratiform and convective precipitation.

3. TECHNICAL APPROACH

3.1 Rain Rate Estimation Procedure

A functional flow diagram of the project analysis approach is shown in Figure 2. The essential steps are: (a) reading of the SSM/I TDRs from the acquired SSM/I data tapes, (b) calibration and antenna pattern corrections applied to the data to obtain brightness

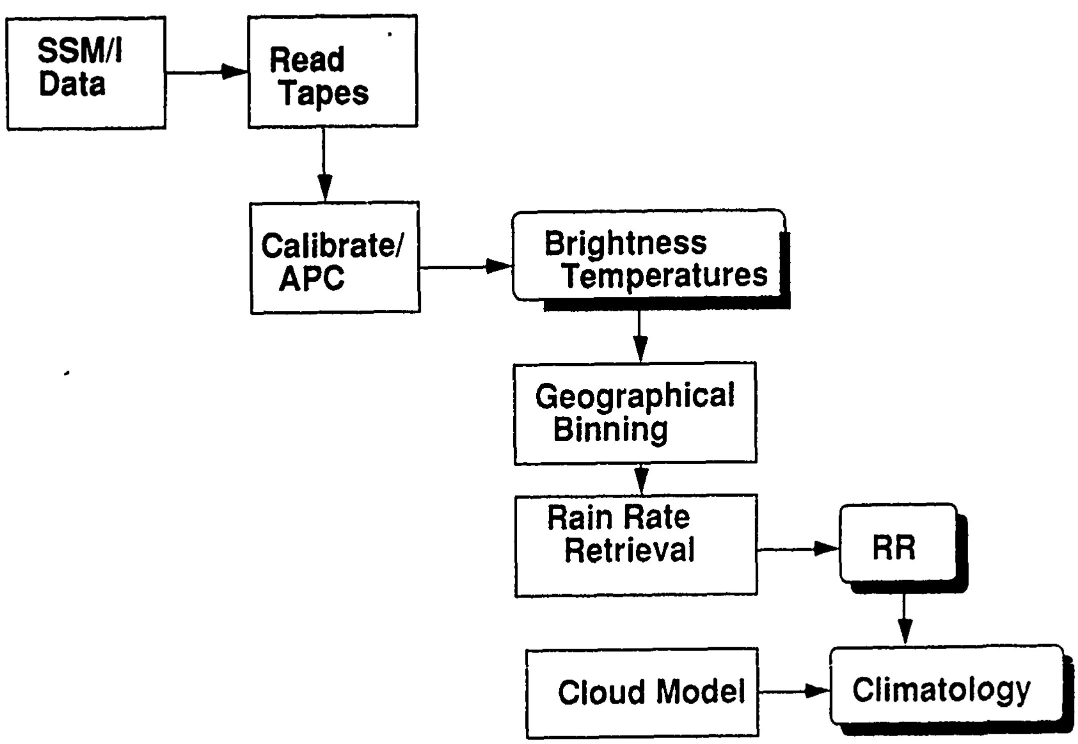

Figure 2. Functional flow diagram for SSM/I data based erosion parameter estimation procedure

temperatures, (c) geographical binning of the data according to the location or each desired site by latitude and longitude, (d) application of the rain rate retrieval algorithm to the data, and (e) evaluation of relevant climatologies. The last step includes calculation of time series for the four month period for the rain rate and integrated liquid water content of precipitation. The latter time series required adoption of appropriate hydrometeor cloud models which are described in Section 5.

The software for reading the SSM/I tapes was implemented on the Air Force Geophysics Laboratory Interactive Meteorological System (AIMS) cluster (Gustafson and Felde, 1988). The unmodified software was run and its performance verified. Certain modifications of the software were made to enhance this project's performance. The first aspect of the software modification concerned the performance time of the entire package. In its unmodified form, the tape reading package took about 8 hours to read an entire SSM/I data tape. Since there are 32 tapes, at best a minimum of 32 tape reads will have to be performed, which would translate into over 6 weeks of work just to extract the data necessary for this project. After closely examining the individual modules and command/data flow design of the software, we optimized the performance time such that it now takes slightly more than 1 hour to read a data tape. The data extracted by the modified software has been verified and validated compared to data extracted by the unmodified package. Software was developed that: (a) loaded the site locations into the program, and (b) filtered the input data stream from any SSM/I data tape such that it would determine "local" data points relevant for each site, and group them into respective data sets. The data is binned using the exact latitude/longitude coordinates of each site such that a region defined by a square, whose center is the point in question, is generated. Any data points which fall within this defined region are considered associated with the point in question. Upon completion of this filtering, a file for each region is written, containing the data observed by the SSM/I for the time period in question. Software to read the SSM/I tapes and do the geographical binning by site is contained in Appendix A. A sample output from the tape reading algorithm is contained in Appendix B. Output are the time (number of seconds since the SSM/I sensor was first turned on), latitude, longitude and brightness temperatures for 19.35 v,h, 22.235, and 37 v,h GHz. The 85.5 GHz channel is read in a second pass due to the different sampling.

A data display software package was also prepared that utilizes NCAR and GKS routines to project the user's choice of either an orthographic, or cylindrically equidistant projection of the earth, and then superimposes either the data observed for a specific site, or the surface scan track for the SSM/I sensor during the periods in question. This software is given in Appendix C. Sample map output illustrating the data density as a function of site at various scales is shown in Appendix D.

Software was also written to evaluate the desired climatologies. These elements include: (a) the calculation of average rain rates and spatial standard deviations within each site region, and (b) the evaluation of liquid water content and integrated liquid water content time series based on the adopted hydrometeor cloud parameterization. This software is also provided in Appendix A.

3.2 SSM/I Data Set

A list of the SSM/I data used in this study is given in Appendix E. Provided are: (a) the tape number, (b) the beginning and end time of data set, and (c) the number of files.

The data files were acquired as part of this study and are available for further analysis. The software capabilities assembled and developed during the course of this pilot study, i.e. data reading, data categorization, data plotting, and data analysis, should be generally applicable to the analysis of this SSM/I data set.

While no comprehensive examination of the data set was made for purposes other than those of this study, it should be noted that this global data set should be extremely useful for a variety of other study purposes.

4. SSM/I RAIN RATE CLIMATOLOGIES

4.1 Eurasian Sites

The study focused on eleven USSR stations of the Environmental Definition Program. Data on these sites was obtained from GL. The eleven sites are: (a) Aktyubinsk, (b) Blagoveschensk, (c) Chita, (d) Kiev, (e) Leningrad, (f) Mo᷊ ow, (g) Murmansk, (h) Perm, (i) Semipalatinsk, (j) Simferopol, and (k) Tashkent. Tne latitude and longitude coordinates for these sites used in the study can be found in subroutine "estreg" in Appendix A.

Of these sites, Murmansk is the northernmost and Tashkent is the southernmost. Blagoveschensk and Chita are in the far east bordering China. Leningrad, Moscow, and Kiev are the most western sites. Murmansk is the only coastal site. For the purposes of this study all of the sites were treated as land based.

This study did not call for the collection or investigation of conventional data sources such as surface and upper air data which might be available for these locations or for the comparison of the SSM/I derived rainfall rate climatologies with these data. In retrospect, this is an important consideration. Essentially, the subsequent analysis assumes that the statistical relationship between rain rate and brightness temperature inherent in the SSM/I algorithm regression coefficients (which were validated over the United States and the United Kingdom), are equally valid over the set of Eurasian sites.

4.2 Site Specific Rain Rate Climatologies

Referring to the data flow diagram presented in Figure 2, the next step in the data processing is the coding and application of the University of Wisconsin SSM/I rain rate retrieval algorithm to the four month data set. This has been accomplished. Data for each of the eleven sites was binned according to lat/long and time tag and rain rate retrievals were performed as a function of field-of-view within 400 km boxes centered at each site. This bin size was selected somewhat arbitrarily, however, consideration was given to capturing precipitation events of synoptic scale which passed in the vicinity of the site as well as mesoscale/convective activity. Considerations of time-space sampling for area-averaged precipitation (WMO, 1985) were considered in formulating our approach, however, there was insufficient time to fully explore these issues.

In addition to the spectral information available in the SSM/I brightness temperature data used to derive the surface rainfall rates, it was recognized that the spatial distribution of rain within the binned area could be used for the purpose of helping to characterize the meteorological properties of the situation. This information is particularly useful to aid in the selection of an appropriate parameterization of precipitation liquid water content (both vertical distribution and integrated) based on the SSM/I derived surface rain rates. It is the liquid water content which can be related to reentry vehicle erosion.

For this reason, both the average daily rain rate (defined as the simple arithmetic average of the individual SSM/I derived rain rates falling within the site specific bin) and the spatial standard deviation (SD) within the bin were evaluated to analyze the spatial coherence of the rain rate field. These data were plotted as time series to produce rain rate climatologies for each site for the four month period. Climatologies for each site are illustrated in Figures 3-13. Illustrated are average rain rate (Figs 3a-13a) and standard deviation (Figs. 3b-13b), respectively. The time series are labelled in days from 1 June 1989, the beginning of the four month data set. All time series plots have been put on a common scale (truncated at 2.5 mm/h) so that intercomparisons can be made.

Examining Figure 7a for Leningrad, it can be seen that there are obvious high (in a relative sense averaged over 400 km squares) rain rate situations (e.g. days 60-65) and low rain rate days (e.g. 35-45). The standard deviations are also illustrative (Fig. 7b). For days 60-65, the high rain rates are accompanied by a large spatial standard deviation (also days 27-30, 75, and 82). This might be indicative of cellular convection. Moderate rain rates with smaller standard deviations might indicate more uniform precipitation. The Leningrad data set does not show this behavior.

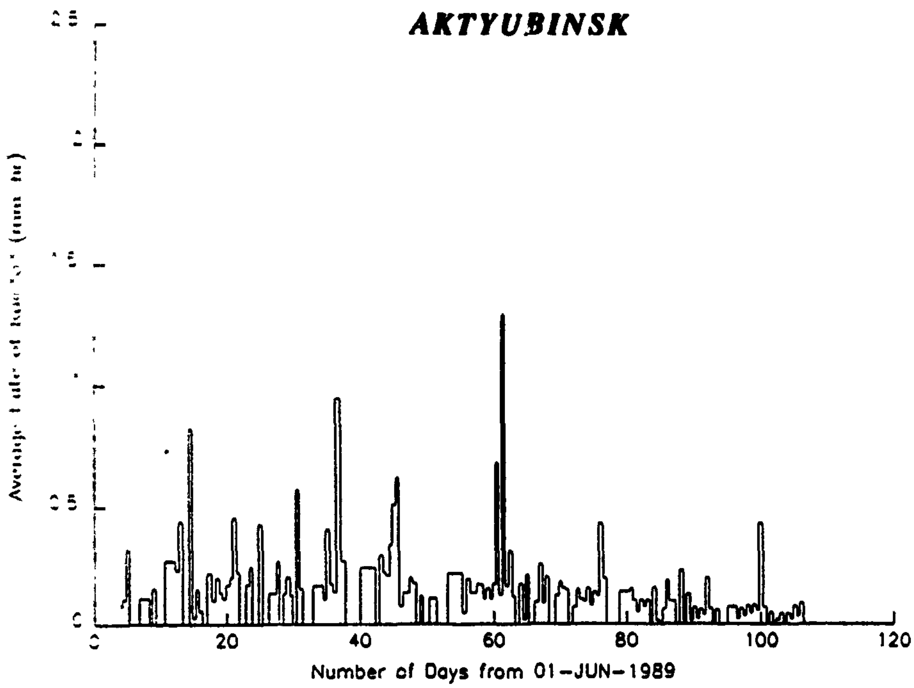

Figure 3a. Sample time series of SSM/I derived rain rate: average rain rate.

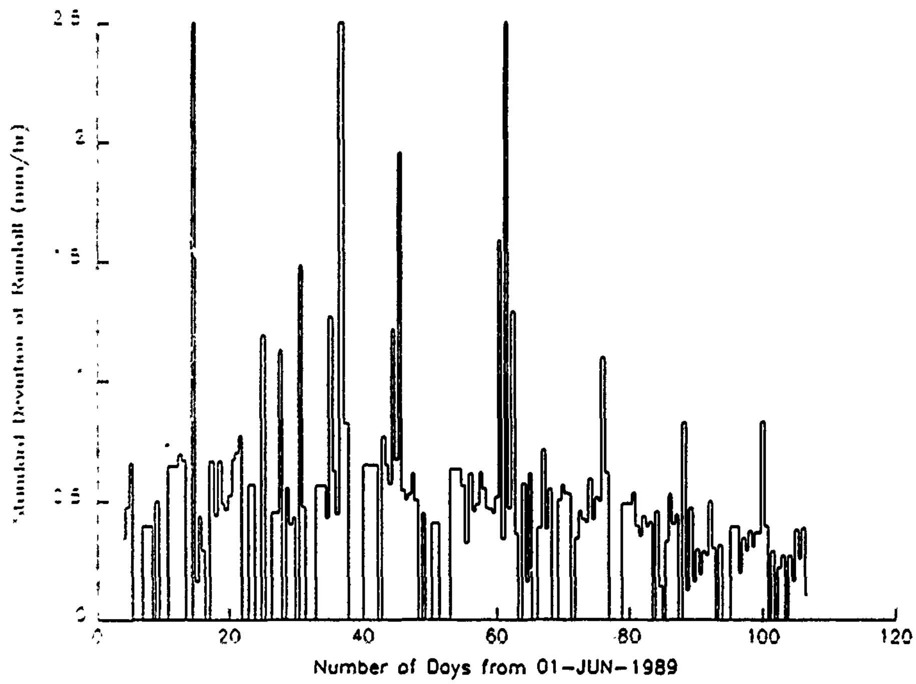

Figure 3b. Sample time series of SSM/I derived rain rate: standard deviation.

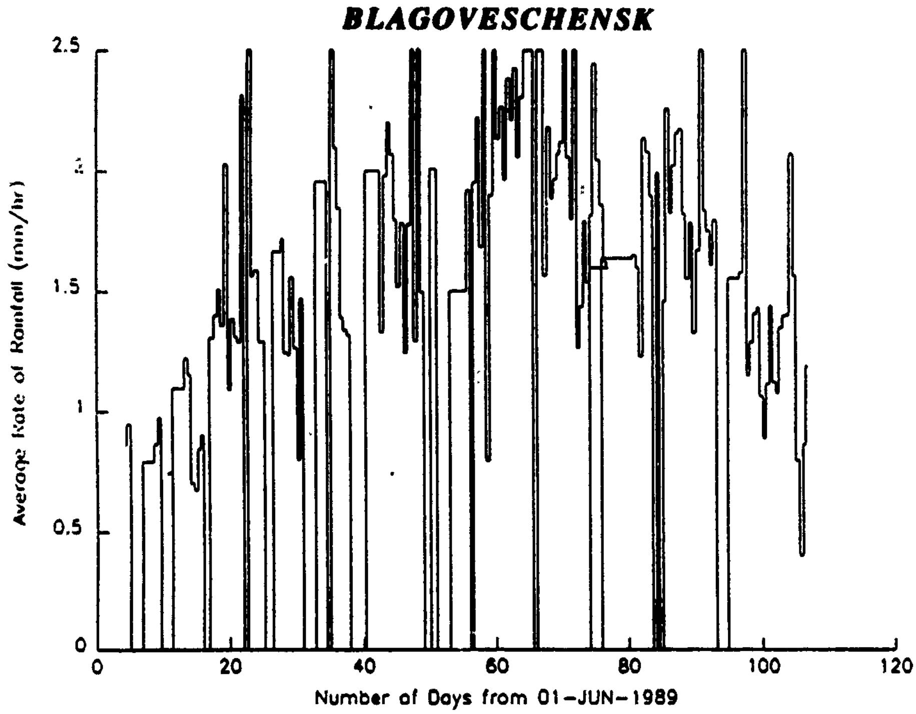

Figure 4a. Sample time series of SSM/I derived rain rate: average rain rate.

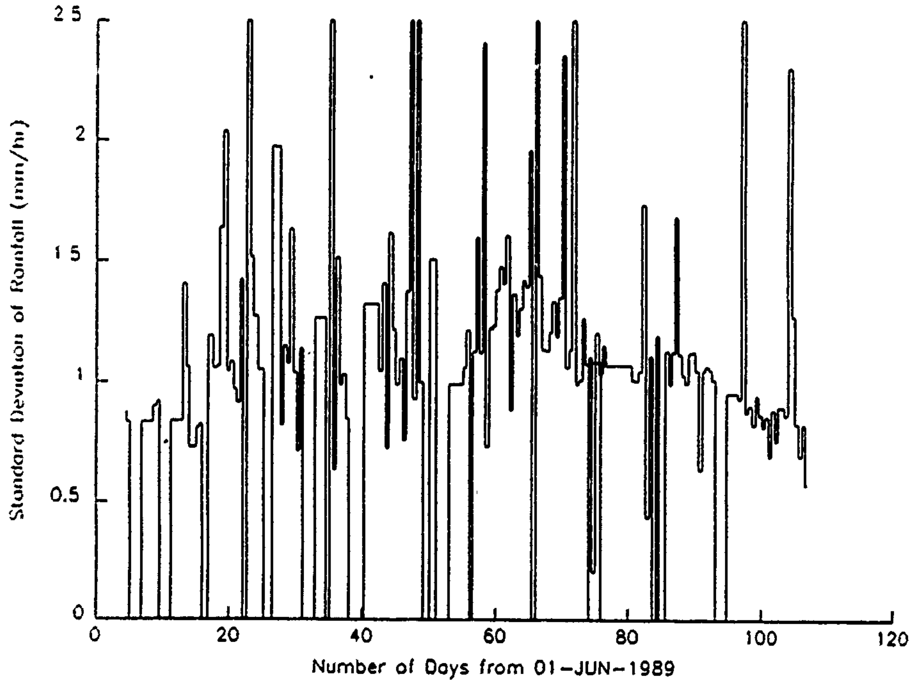

Figure 4b. Sample time series of SSM/I derived rain rate: standard deviation.

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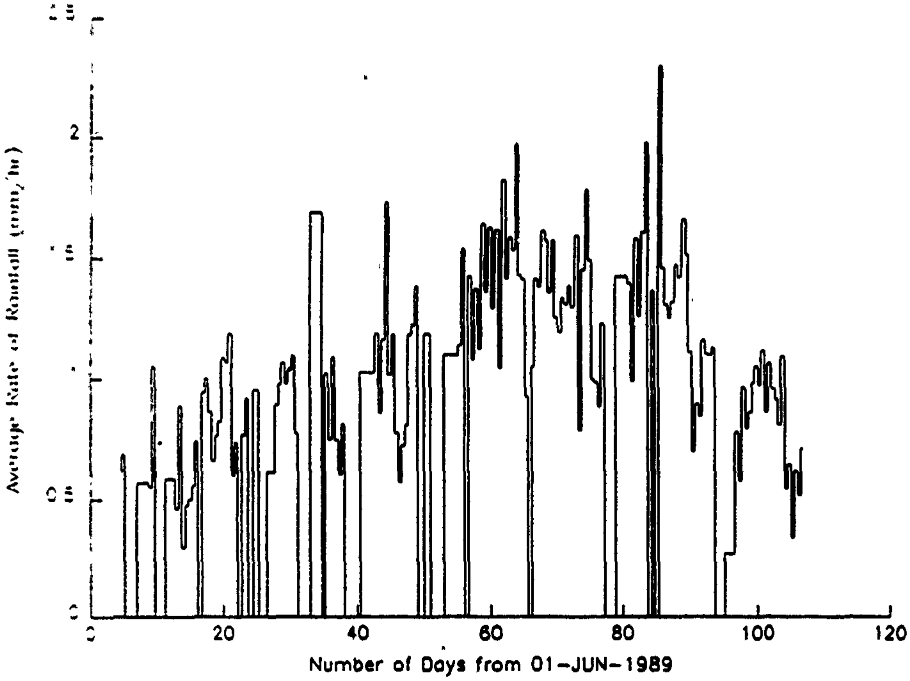

Figure 5a. Sample time series of SSM/I derived rain rate: average rain rate.

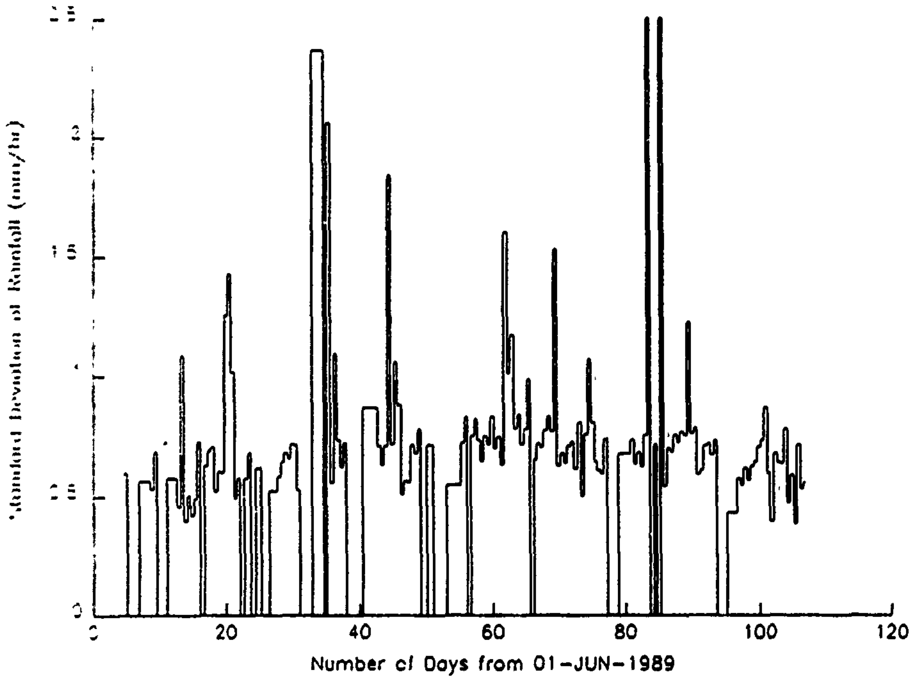

Figure 5b. Sample time series of SSM/I derived rain rate: standard deviation.

KIEV

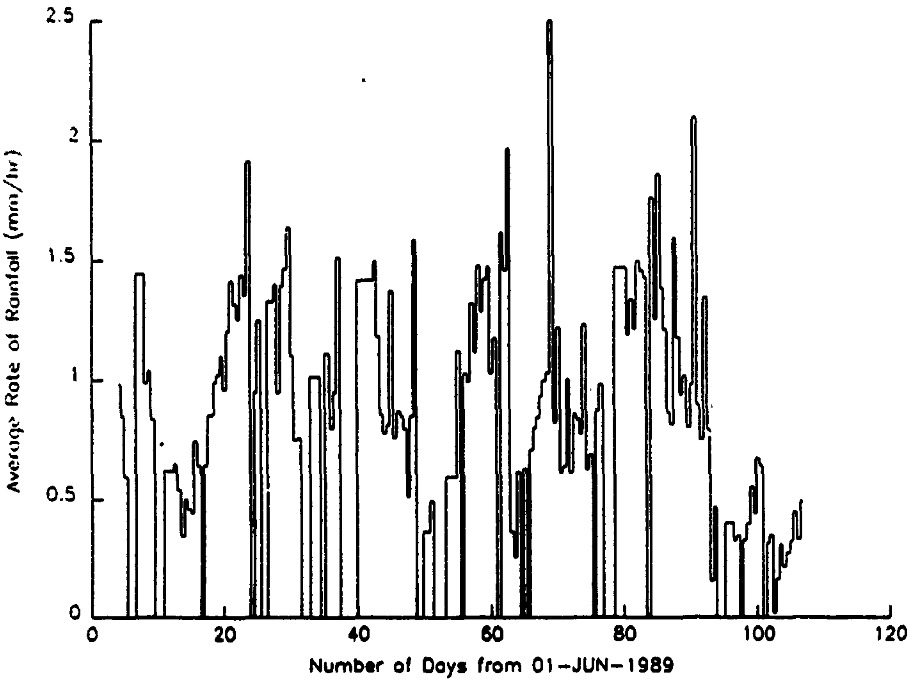

Figure 6a. Sample time series of SSM/I derived rain rate: average rain rate.

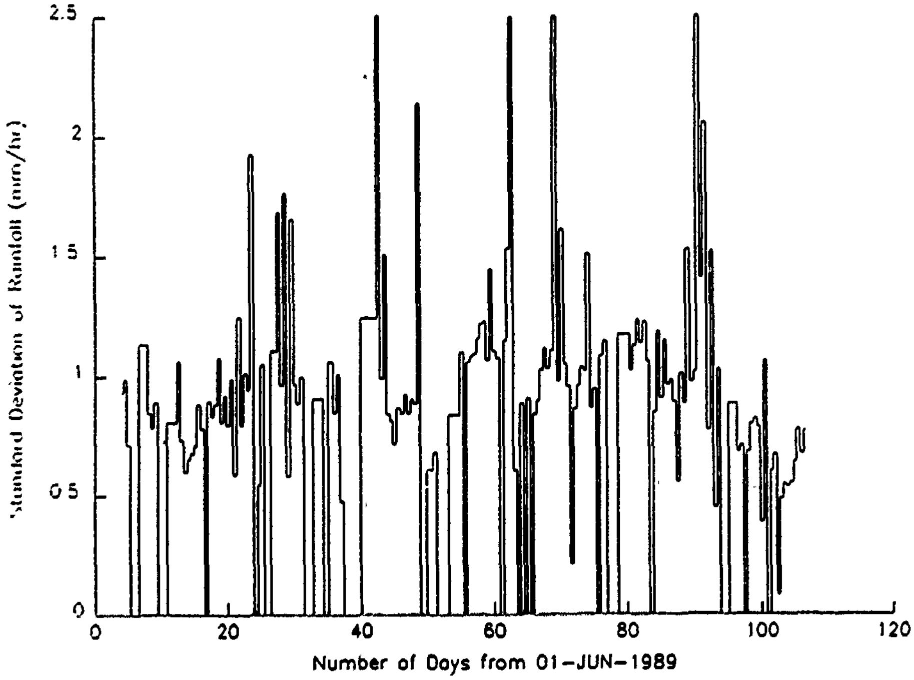

Figure 6b. Sample time series of SSM/I derived rain rate: standard deviation.

LENINGRAD

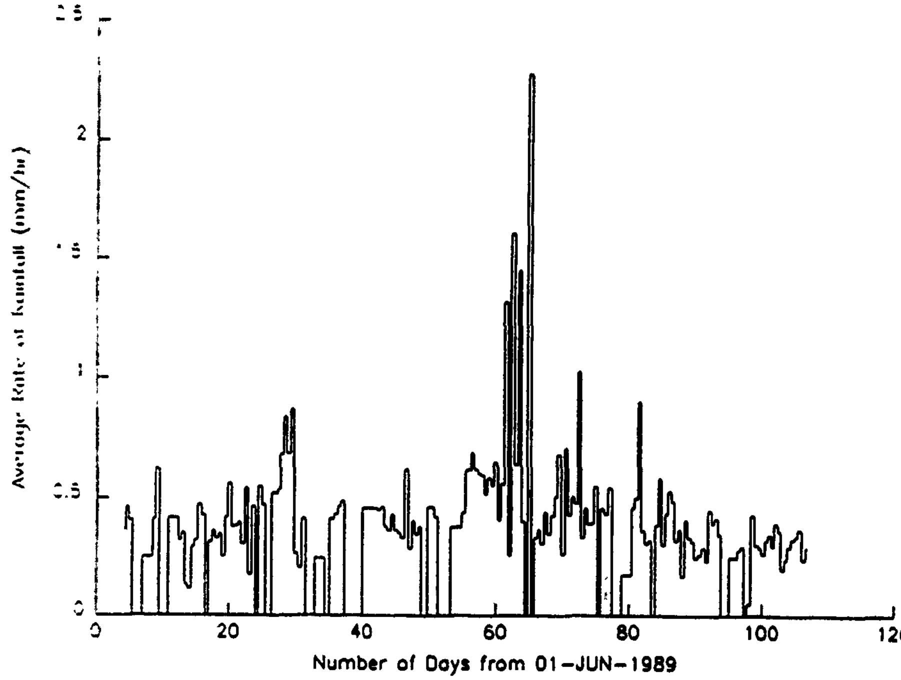

Figure 7a. Sample time series of SSM/I derived rain rate: average rain rate.

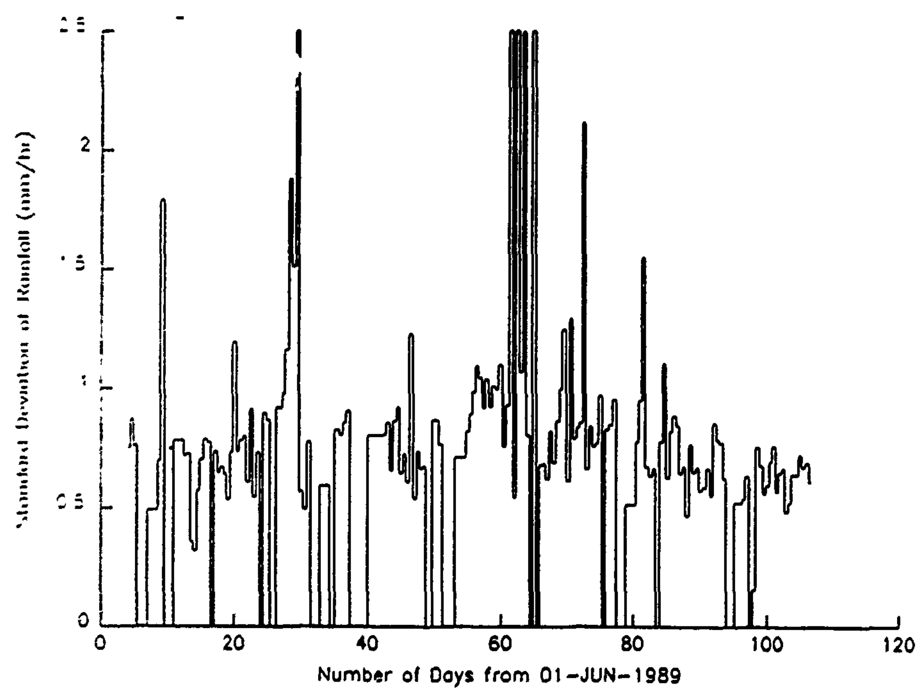

Figure 7b. Sample time series of SSM/I derived rain rate: standard deviation.

MOSCOW

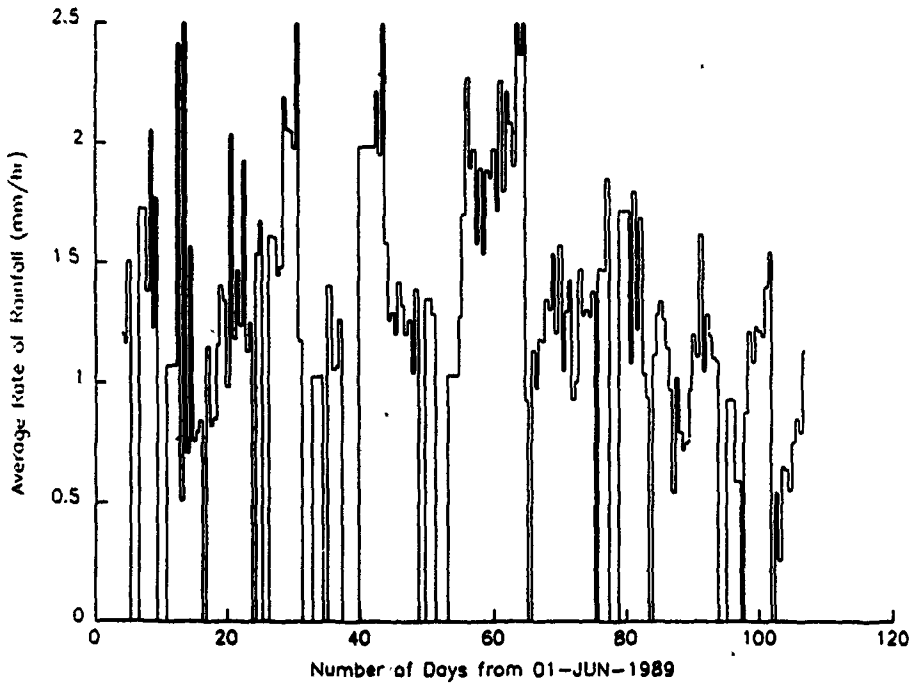

Figure 8a. Sample time series of SSM/I derived rain rate: average rain rate.

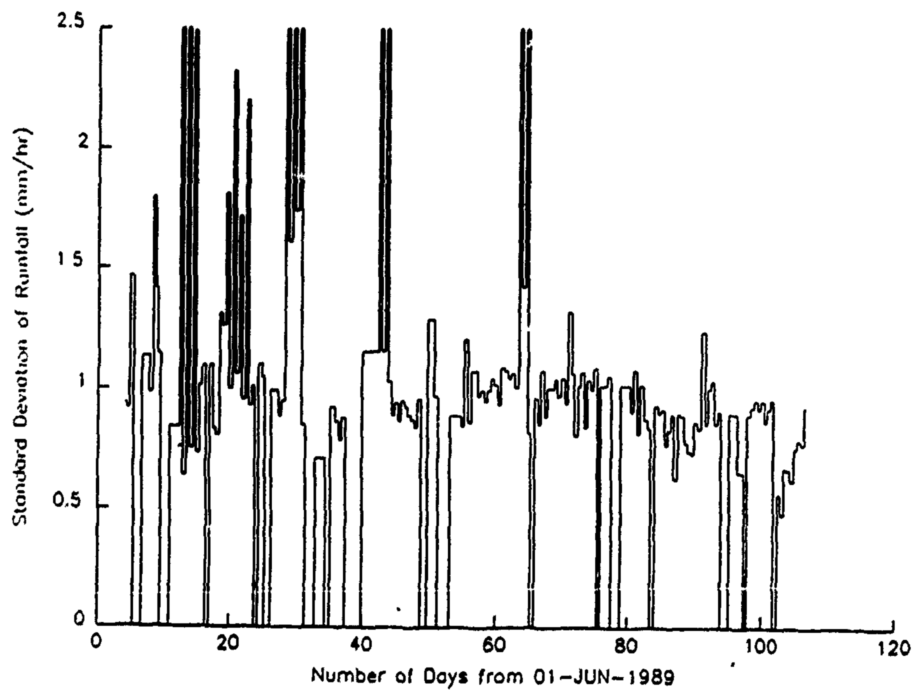

Figure 8b. Sample time series of SSM/I derived rain rate: standard deviation.

MURMANSK

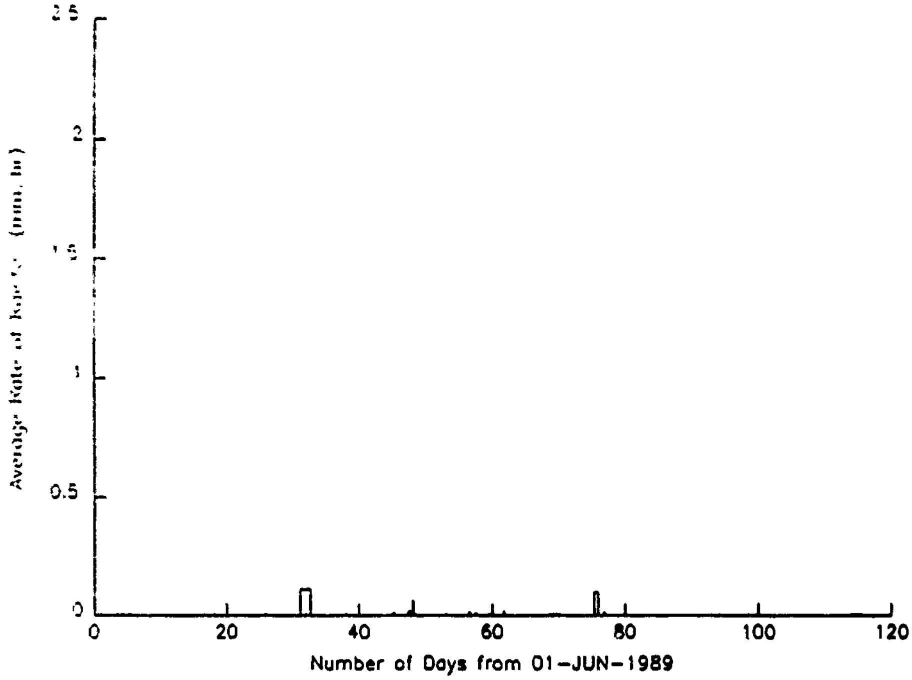

Figure 9a. Sample time series of SSM/I derived rain rate: average rain rate.

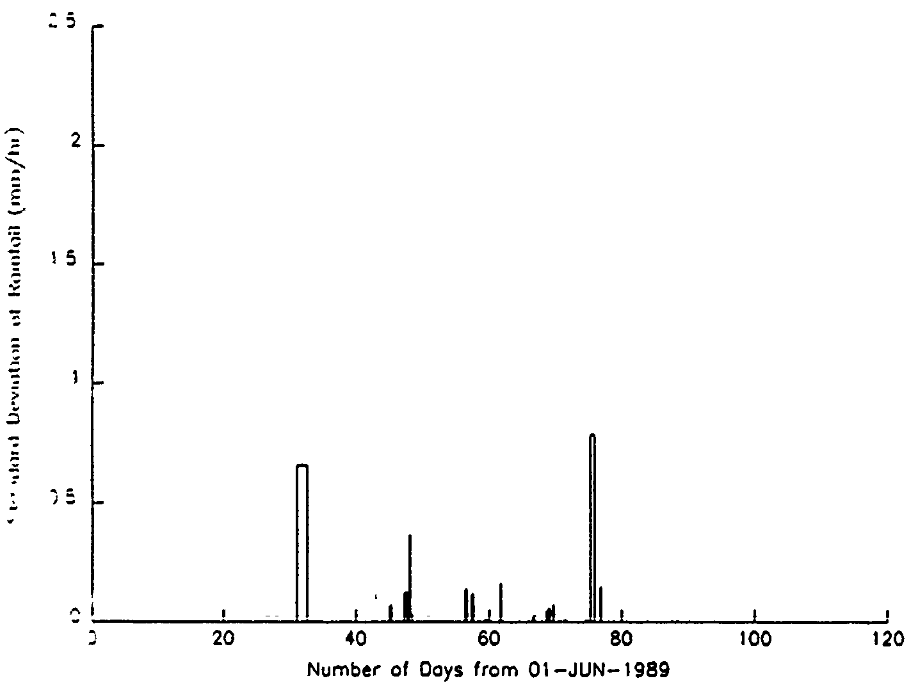

Figure 9b. Sample time series of SSM/I derived rain rate: standard deviation.

PERM

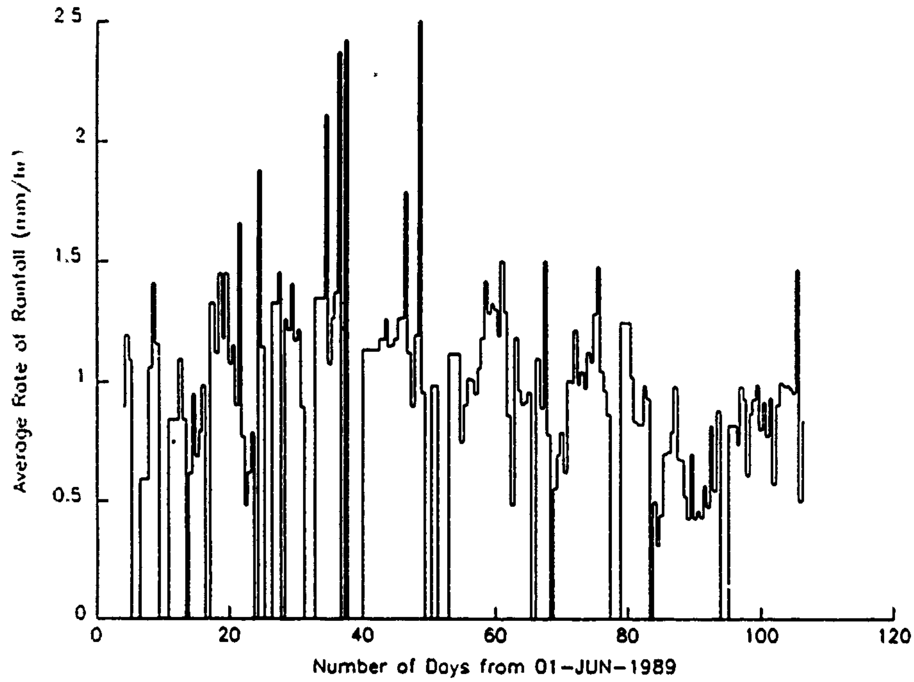

Figure 10a. Sample time series of SSM/I derived rain rate: average rain rate.

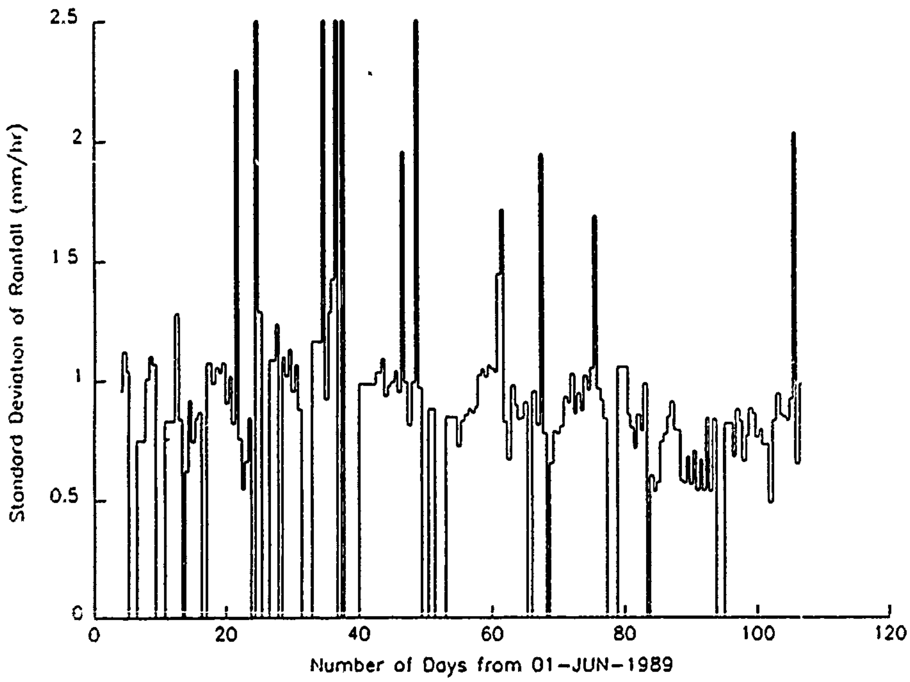

Figure 10b. Sample time series of SSM/I derived rain rate: standard deviation.

SEMIPALATINSK

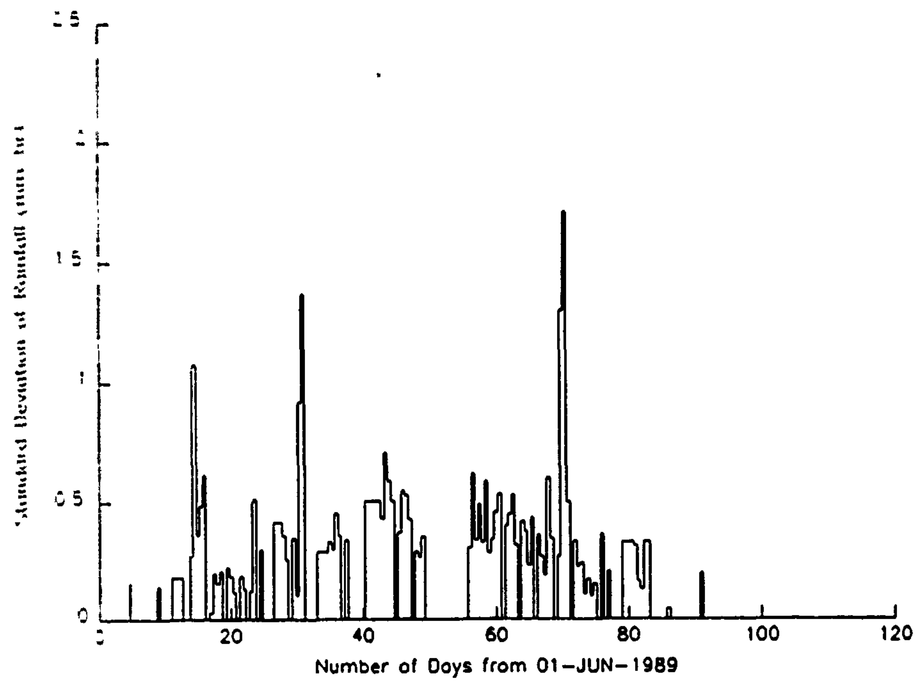

Figure 11a. Sample time series of SSM/I derived rain rate: average rain rate.

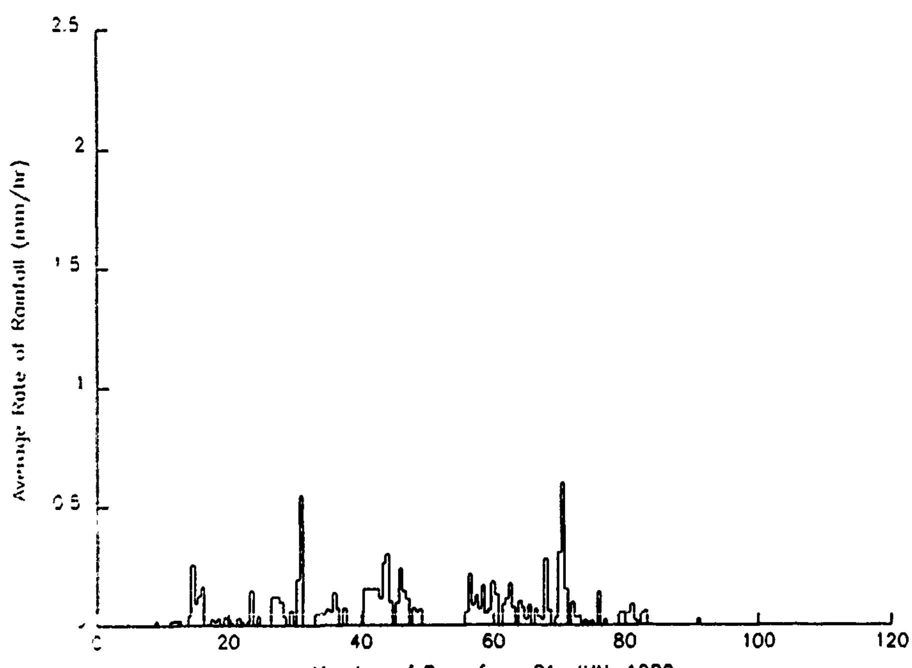

Figure 11b. Sample time series of SSM/I derived rain rate: standard deviation.

SIMFEROPOL

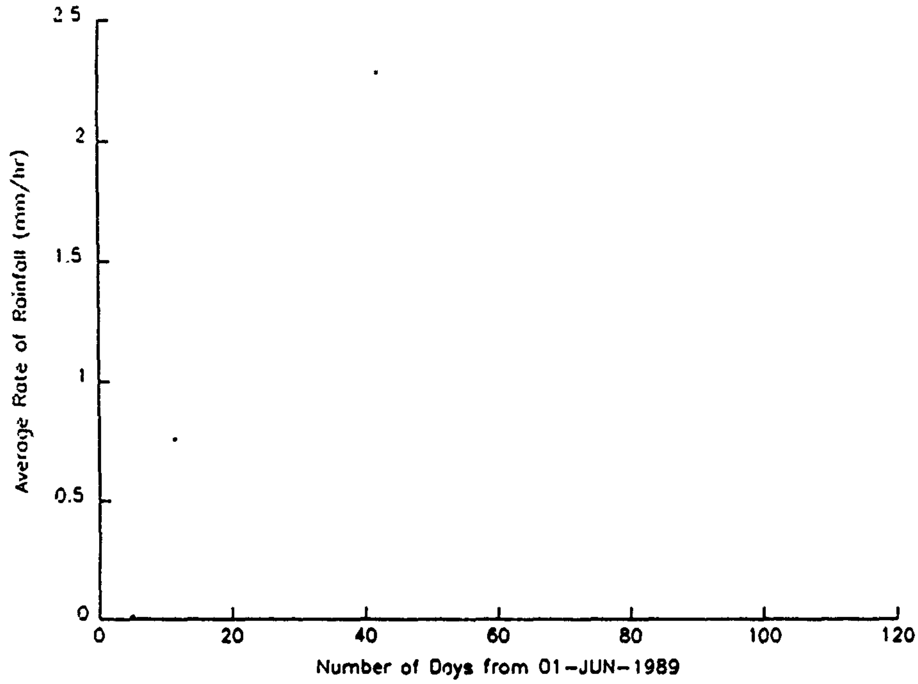

Figure 12a. Sample time series of SSM/I derived rain rate: average rain rate.

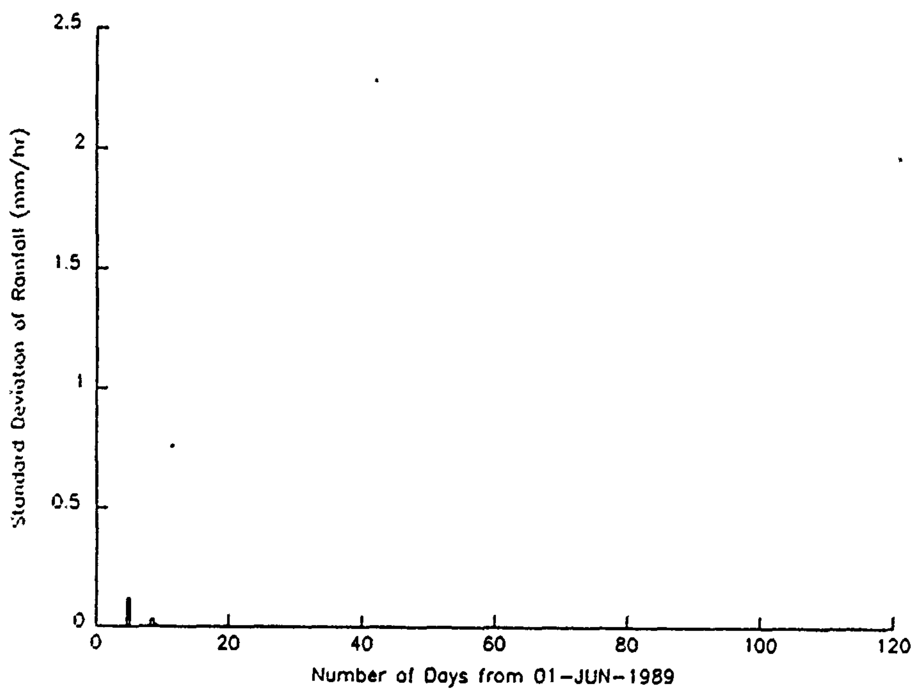

Figure 12b. Sample time series of SSM/I derived rain rate: standard deviation.

TASHKENT

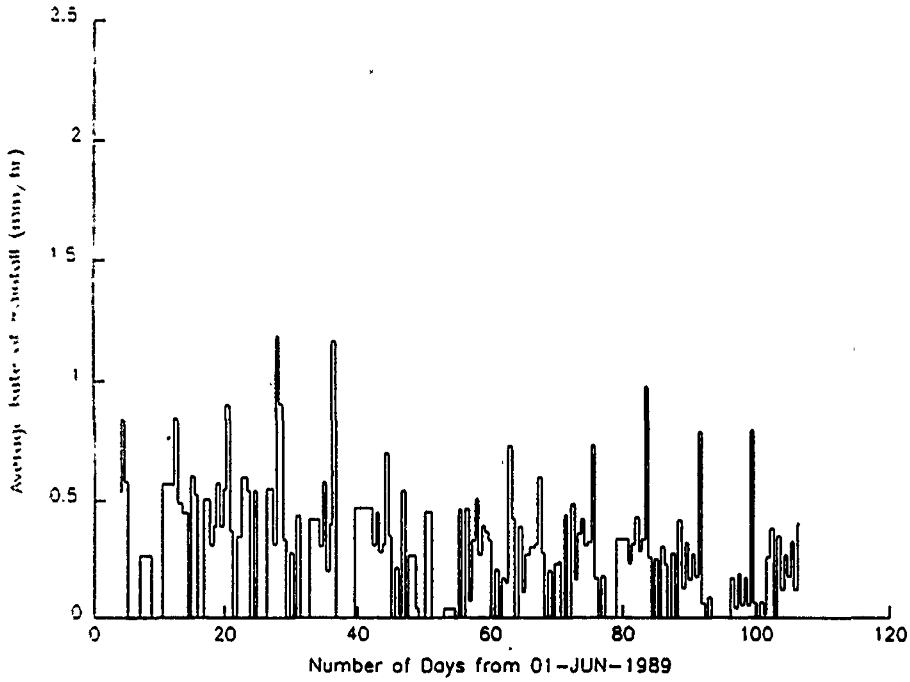

Figure 13a. Sample time series of SSM/I derived rain rate: average rain rate.

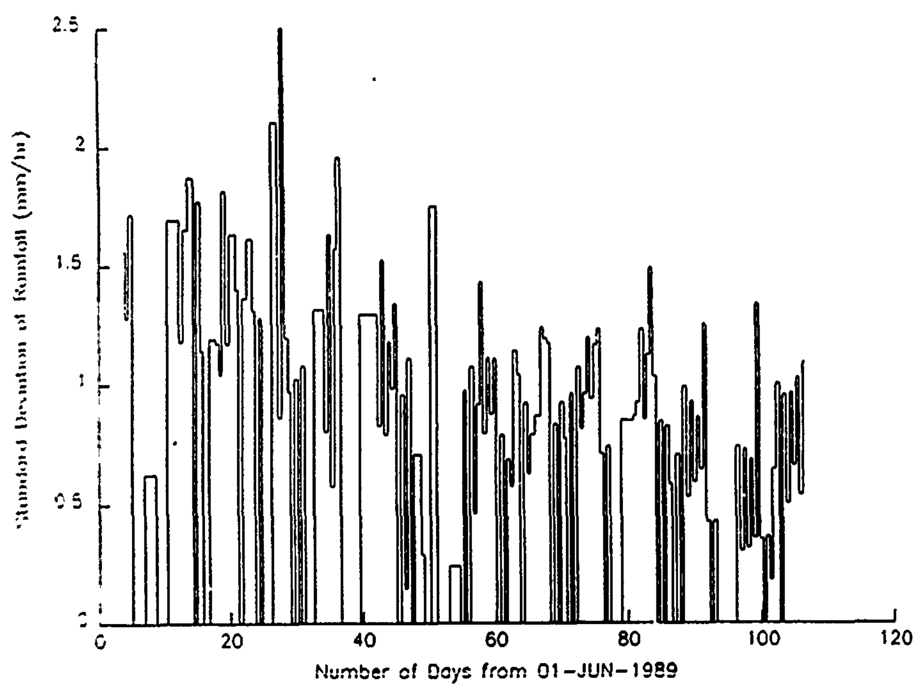

Figure 13b. Sample time series of SSM/I derived rain rate: standard deviation.

In addition to the time series, we can look at the contoured daily SSM/I derived rain rates for given sites. This gives the opportunity to study the structure of the precipitation for a desired day at the resolution of the SSM/I footprints.. An example is shown in Figure 14 for Moscow. Based on the time series data given in Figures 8a,b, the figure illustrates: (a) a low rain, high SD case (day 15, [4]), (b) a high rain, high SD case (day 44, [0.4]), (c) a high rain, low SD case (day 61, [0.2]), and(d) a low rain, low SD case (day 95, [0.1]). The numbers in brackets are the contour intervals on each plot in mm/h. A heavy convective cell can be seen in Figure 14a, but there is little precipitation elsewhere resulting in a very low average rate for the region. Cells of moderate intensity can be seen in Figures 14b,c also. In these cases most of the region is active resulting in high average rainfall rates. In Figure 14d by comparison, there is light rain throughout the region (note the contour interval changes). The importance of examining both the average rainfall rate and the spatial standard deviation in characterizing an event is obvious.

4.3 Discussion

The type of meteorological event resulting in precipitation is likely to be related to the distribution of hydrometeor signatures within the region examined. High standard deviation indicates that the precipitation is scattered over the area of the view box, e.g. convective type precipitation, and the low standard deviation means the rainfall is uniform over the area of the view box, e.g. stratiform type precipitation. If high rainfall rate is associated with high standard deviation, it might be precipitation from individual thunderstorms. The passage of a frontal rainband, on the other hand, could be characterized by high rainfall rate associated with low standard deviation. The association of low rainfall rate with low standard deviation could mean the passage of a warm front, and/or precipitation from stratiform cloud. If low rainfall rate associates with high standard deviation, it could mean that the weather system which causes precipitation passes through only part of the view box. The other possibilities of low rainfall rate with high standard deviation could indicate that the weather system is too weak to produce a sufficient amount of precipitation and/or the environment is too dry, thus only part of the rainfall could be detected at the surface when the weather system passes through the view box.

Regions of convective and stratiform precipitation are hard to define, because several well-developed and decaying convective cells might still overhang into the stratiform region (Tao and Simpson, 1989). Therefore, it is hard to use the rain rate to clearly define the type of precipitation. From the data, we can see that the two stations located at the eastern part of the USSR have higher rainfall rate and higher standard deviation. The difference between these two stations might be that individual thunderstorms occur in Blagoveschensk more than Chita. Although both data show that the frontal rainfall occurs very often at both sites. It might be that the Blagoveschensk site is much closer to the ocean. Other sites have less rainfall rate and show the situation of steady precipitation occurs more frequently in these locations, despite the fact that some individual thunderstorms (maybe afternoon thunderstorms) occurred in the period.

We employ these spatial coherence concepts to the application of our precipitation cloud models (Section 5) to the determination of integrated hydrometeor liquid water content in Section 7.

5. CONVECTIVE CLOUD MODEL PARAMETERIZATIONS

Task 2 required definition of cloud models to relate SSM/I derived surface rain rates to precipitation liquid water content. We have completed this task by defining parameterizations of liquid water content vertical distribution and total integrated liquid water content of precipitation for stratiform and convective rain with the capability to decide between the two using the spatial coherence data derived from the SSM/I rain rate fields.

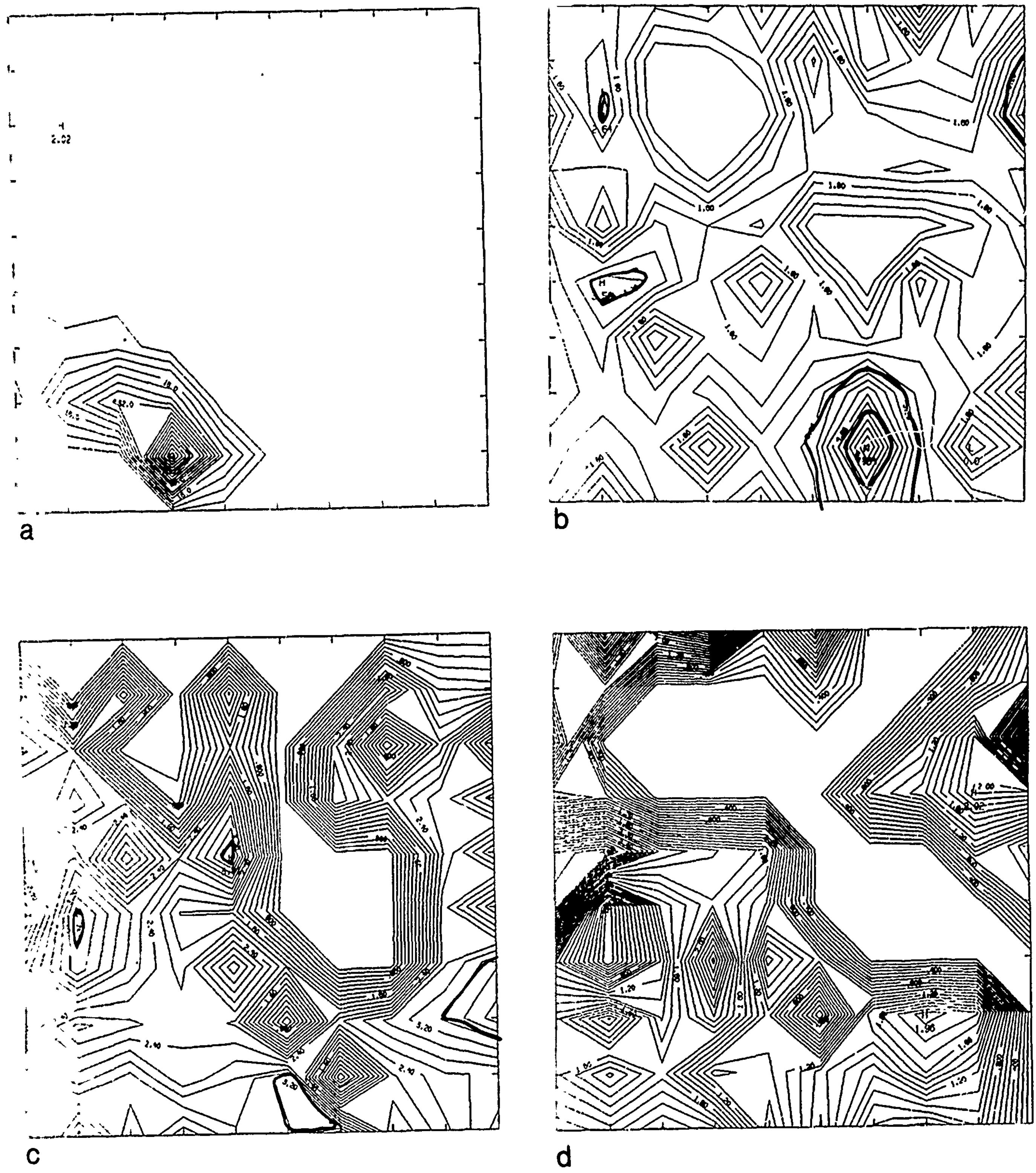

Figure 14. Sample contour map of SSMI/I derived rain rate.

5.1 Cloud Process Overview

The formation of raindrops or ice crystals involves complicated microphysical and dynamical processes. The thermodynamical effects from the phase changes of water in turn affect the evolution of the weather system in which those processes are embedded. Several papers have studied the dependence of the formation of precipitation on microphysical and dynamical processes. The results show that both the microphysical and the dynamical processes are important. For example, the growth and fallout of rain can interact with the updraft, or can evaporate in the subsaturated downdraft region, which in turn, affects formation of the hydrometeors. Since measurement of the microphysical processes is difficult, the only way to simulate these processes is to parameterize them with respect to the large scale dynamical motion. Due to recent theoretical developments and laboratory experiments, several models have been proposed to treat these processes and some of the results have been compared with the measurements from the field experiments.

In this study we conducted a survey of different hydrometeor cloud models focusing on those which can be used to simulate the vertical distribution of liquid water content based on the surface precipitation rate. A simple parameterized relationship based on climatological statistics is derived and the vertical distribution of the liquid water content is expressed as a function of height and surface rainfall rate.

5.2 Review of Cloud Vertical Distribution Models

5.2.1 Simulation Studies

A high correlation between cloud top height and rainfall rate has been shown by Zawadzki and Ro (1978) and Dennis et al. (1975). Adler and Mack (1984) used a one dimensional cloud model to study the relationship of the thunderstorm cloud height-rainfall rate and the cloud height-volume rainfall rate with satellite infrared data. The variation of the vertical velocity and precipitation efficiency has been shown to dominate both the slopes and the difference of the two curves which represent the relation between the cloud top height and the rainfall rate. Information on the convection from numerical model output is needed to derive the cloud-rain relationship, and the vertical shear is considered to be the important parameter to estimate the volume rainfall rate,

Larger scale factors such as the synoptic environment, topographical situation, and the location of the station with respect to the thunderstorm or frontal rainband are important in determining the desired relationship. Therefore, empirical rain estimation techniques developed in one area cannot be applied directly to other areas. Simple adjustments may be inadequate because of differences in slopes of rainfall rate-height in different locations. To determine convective rain rate and the volume rain rate, the moisture source, the vertical velocity, and the rain efficiency are important. Additionally, the updraft area is important in determining the volume rain rate. Ideally all of these data should be used to adjust the value of the input parameters to get a more representative profile. Thus, full use of a numerical cloud model with the inclusion of the adequate dynamical processes is necessary.

Kessler (1959, 1961, 1963) devised parameterized equations for microphysical processes (cloud water and rain) with an assumed vertical motion profile and water generation function. Simpson and Wiggert (1969) used a one dimensional cloud model with the Kessler (1965) type of parameterization to study the precipitation in tropical cumulus clouds. The microphysical processes include the autoconversion from cloud water to precipitation water, collection and coalescence, terminal velocity, and fallout of the precipitation with the evaporation due to entrainment of drier air in a downdraft. The initial conditions include the information from the sounding data: the saturation at cloud base or lifting condensation level at environment temperature, the excess of the temperature at cloud base, and the vertical velocity at the cloud base. The assumptions made with the above model rule out the feedback between the microphysical and dynamical processes in the

model. The new model corrects this problem and the results are more reasonable. However, the treatment of the ice phase is insufficient and, therefore, the parameterization needs to be updated in order to include the ice phase change effect. The results from this study reveal that more complicated microphysical processes should be introduced and the interaction with dynamical effects should be included. The amount of the rain which reaches the ground as precipitation cannot be calculated in the context of this study and, therefore, we cannot use the information of the surface rainfall rate to derive the vertical distribution of the liquid water content.

Cotton (1972a, 1972b) studied precipitation processes within the supercooled cumuli environment, and the interaction between the microphysical process and cloud dynamics. Precipitation formation in warm clouds (1972a) and a model which includes the ice phase (1972b) have been studied. A more complicated parameterization to simulate the microphysical processes in midlatitudes, which includes the processes of phase change between cloud ice, snow and graupel, cloud water and rain water has been developed by Lin et al. (1983). This parameterization is used in the study by Rutledge and Hobbs to investigate the precipitation within warm clouds (1983) and seeded ice phase (1984) environments. Three different precipitation zones categorized according to the surface precipitation rate are described in the study. Their results are in a good agreement with those from field experiments.

Tao and Simpson (1989) use the Kessler type of microphysical (cloud water and rain water) and Lin et al. (1983) parameterizations (cloud water, rain, cloud ice, snow and graupel) to study the structure of tropical squall-type convective lines. Two-dimensional models and three dimensional models have been used. The role of the ice-phase and the mesoscale ascent in middle and high-levels has also been investigated. The model output of the ice runs have been compared with that of the ice-free runs. The results show that the ice-phase microphysical processes are crucial for a realistic stratiform structure and its precipitation statistics. Also, their results show that the mesoscale ascent in the middle level was the main mechanism responsible for the extended region of the stratiform precipitation at the rear of the squall line, which has been suggested by Rutledge (1986).

5.2.2 Measurement Studies

Wei et al. (1989) use five different methods to estimate path-integrated (columnar) cloud liquid water. The methods include one-channel (31.65 GHz) and two-channel (20.6 GHz and 31.65 GHz) physical retrievals, the standard method of linear statistical inversion using two channels, and two statistical methods that proceed from an initial determination of several empirical regressions between measured and computed quantities. With brightness temperature data and/or the absorption coefficients (for oxygen, the water vapor and the cloud), the optical thickness of the clear air and the cloud water can be calculated. The calculation of cloud water content with microwave radiometer data is encouraging, however, their results lack comparison with independent observations, e.g. radar.

During the period of interest, there is no precipitation occurring in the study of Wei et al. (1989), thus they only estimate the cloud water content without estimating the precipitation amount. The study needs sounding data (vertical distribution of pressure, temperature, humidity, and cloud water content), and knowledge of the absorption coefficients to resolve the answer. Also, a hypothetical liquid water profile from an archival sounding needs to be specified in order to calculate the radiative transfer. These conditions require almost the same effort of running a more sophisticated dynamical cloud model.

Heymsfield and Fulton (1988) studied the measurement of precipitation in thunderstorms from high altitude remote aircraft. In their studies, the comparisons between the microwave data at 92 GHz and 183 GHz with the data from radar, lidar or GOES IR data reveal that using 92 GHz microwave data to detect the rainfall area is advantageous. The liquid water content (LWC) or ice water content (IWC) can be calculated based on the

convective area, IWC for the snow aggregates in the convective region and IWC in nonprecipitating anvil region. The relation of the rainfall rate with the vertical liquid and/or ice structure is unclear in this study.

Wilheit et al. (1982) used the 19.35 GHz and 183 GHz data from a microwave radiometer to study the precipitation in a tropical storm. The tendency of the rainfall rate can be matched by the tendency of the brightness temperature at 92 GHz, and the 183 GHz providing some information on the vertical extent of the frozen hydrometeors. This is a more direct way to determine the vertical distribution of the liquid water, and it is worth further study.

5.3 Discussion

Simpson and Wiggert (1969), Cotton (1972a,b), Rutledge and Hobbs (1983, 1984) and Tao and Simpson (1989) used cloud models to simulate the spatial distribution of the liquid water distribution. Since the vertical distribution of liquid water depends on the stage of evolution, the position away from the core of the updraft and the type of the system, the dynamical processes are as important as the microphysical process. Forvell and Ogura (1988) found that the addition of ice was responsible for the achievement of more realistic scale features in the convective region of the simulated squall line. More complex microphysical process which included the ice-phase parameterization have been simulated by Lin et al. (1983). Rutledge and Hobbs (1984) and Tao and Simpson (1989) show that the model output is in good agreement with the field experiment data. The two-dimensional cloud model of Tao and Simpson (1989) is capable of simulating stratiform precipitation and the areal coverage of the stratiform region. Therefore, if a numerical approach is desired, it is recommended to use this cloud model for the stratiform precipitation cases.

The model of the Rutledge and Hobbs (1984) is good in the situation of frontal rain bands and convective precipitation. In order to obtain the vertical structure of the liquid water from model output, several initial conditions are needed. Using this model requires the specification of additional sources of information. Since the liquid water field from model output is specified at each grid point, a simple relationship between the vertical distribution of liquid water field and surface rain fall rate is unnecessary. If we have more specific description of the liquid water field, the snow field and the cloud water field, the total liquid water content in a column can be obtained by integrating vertically. Also, the rainfall rate is determined by the conditions of the environment, such as the relative humidity, the wind shear and updraft. Therefore, it is hard to find a simple relationship which will satisfy all of the dynamical conditions in determining the vertical distribution of liquid water depending on the surface rainfall rate alone.

An alternative approach to derive a simple relation between the surface rainfall rate and the vertical distribution of liquid water content is using the climatological record. From the result of Adler and Mack (1984), the height-rainfall rate relation is different from place to place. For example, high rainfall rate for moderate and small storms occurs in the coastal regimes, while fairly deep convection in Midwest thunderstorms produces only moderate rain rate (Adler and Mack, 1984). Therefore, our derivation of the relationships between the surface rainfall rate and the vertical distribution of the liquid water content based on the climatological data depend on the geographical distribution too.

In the study of Adler and Mac '1984), the statistical retrievals of columnar liquid water and water vapor are found to be more accurate than physical retrievals. Therefore, we will use the climatological data to derive the simple relationship based on the vertical distribution of the liquid water content from Falcone et al. (1979). The important features of these distributions are (see Figure 15):

(1) A maximum liquid water content is located between the cloud top and the surface (Rutledge and Hobbs, 1983, 1984; Tao and Simpson, 1989). From the model output, the height of the maximum liquid water content is strongly influenced by the

vertical velocity, therefore, the maximum height of the cumulus convection is normally higher than the stratiform precipitation, and

(2) The amount of the liquid water content is nearly uniform below the cloud base, or the liquid water content below the freezing level in the convective region is almost constant with height (Tao and Simpson, 1989).

5.4 Liquid Water Content/Rainrate Relationships

Based on the results from the diagnostic studies, a statistical polynomial fit like the one used in Wei et al. (1989) is used to simulate the climatological profiles for the four precipitation models given in Falcone et al. (1979). Models I-IV (pp. 46-47) correspond to two stratiform (I, II) and two convective (III, IV) models, respectively. The following conditions are used to derive the coefficients of the polynomial fits:

• the liquid water content reaching the surface, M_s, is derived from the rain rate retrieved from the SSM/I microwave,

• the maximum liquid water content is M_m and is at height Z_m,

• the liquid water content at the cloud top (Z_t) is zero,

• the first derivation of the polynomial at the height (Z_m) equals zero, and

• the first derivative of the polynomial at the surface equals zero.

These values are read from Figures 14-17 in Falcone et al. (1979), see Table 3.

The relationship between the rainfall rate and the liquid water content can be found in Falcone et al. (1979) and Simpson and Wiggert (1969). We use the relationship of Falcone et al. (1979)

$$M = 0.07 * RR **0.83 ,$$

where M is the liquid water content (g/m^3) and RR is the rainfall rate (mm/h), and apply it at the surface and use M_s to denote the liquid water content here.

A fourth order polynomial fit is used to simulate convective precipitation (models III and IV). The result, as shown in Fig. 15a, shows the simulation of the vertical distribution of the liquid water content with the polynomial equation and the input values of Z_t, Z_m, M_m, M_s corresponding to the four precipitation categories from Falcone et al. (1979) (Models I-IV, pp 46-47), given in Table 3. The cloud top of curve 2 is lower than that specified by Falcone et al. (1979) in their Fig. 15. If we look at the curves carefully, we can find that the slope is nearly the same above and below the maximum height. In steady rain cases like stratiform precipitation, most of the cloud water and the precipitation is located in the lower troposphere. The maximum liquid water accumulation is near 1 to 2 km, the height of the maximum liquid water field is lower. Thus, if the slopes above and below the maximum height are the same, the liquid water content will vanish at a height below the specified cloud top. For this reason, only curves 3 and 4 are used to model convective rain.

A third order polynomial equation is used to simulate the stratiform precipitation. Three tests have been run with the equations satisfying four out of the five given

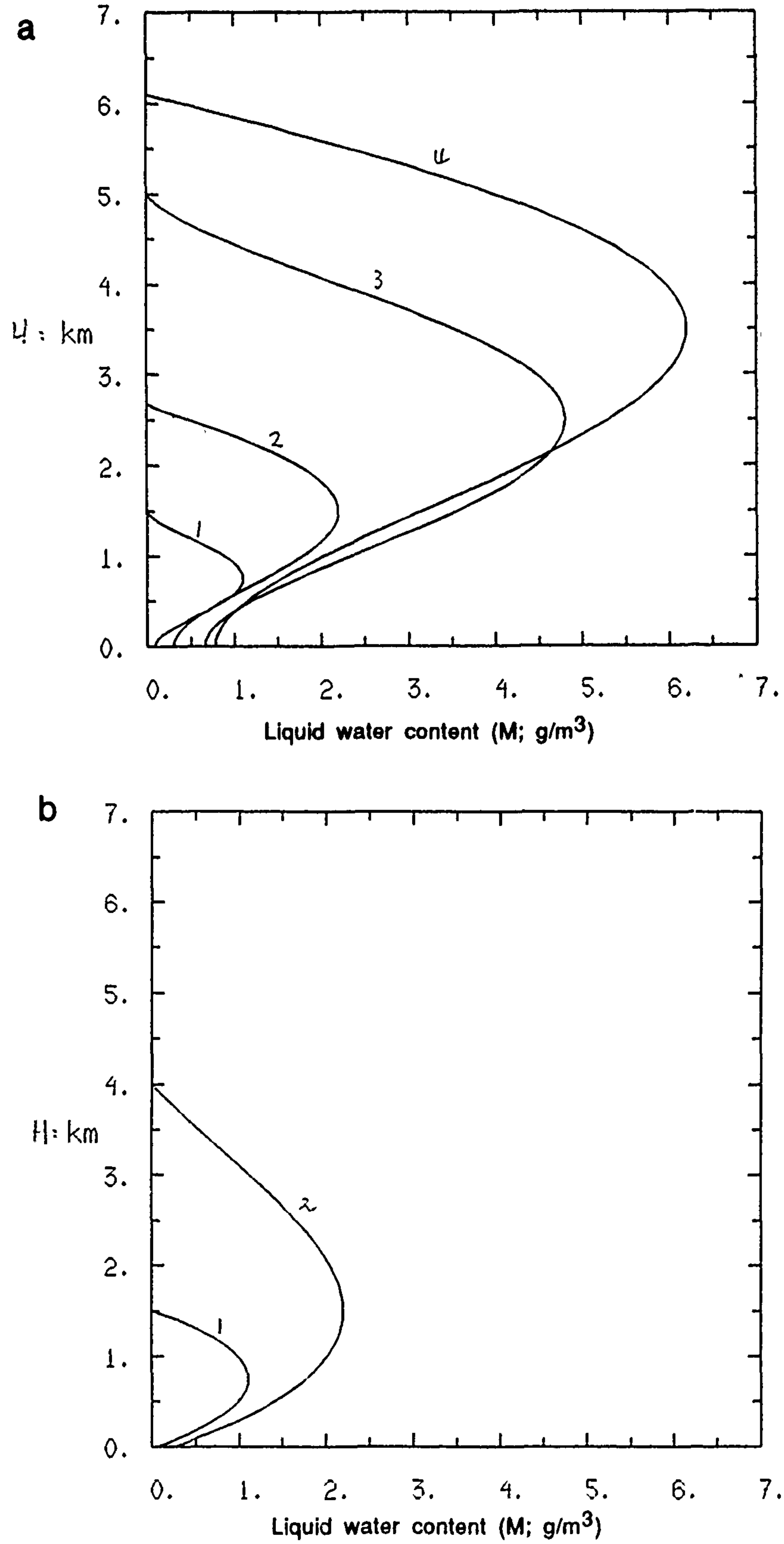

Figure 15. Simulation of the vertical distribution of the liquid water content with polynomial equations (see text).

Table 3. Polynomial Fit Data

Curve	RR (m/h)	Z_t (km)	Z_m (km)	M_m (g/m^3)
1	1.25	1.5	0.75	1.1
2	5.00	4.0	1.50	2.2
3	12.50	5.0	2.50	4.8
4	15.00	6.1	3.50	6.2

conditions. Test one satisfies the conditions 1, 3, 4, 5, test two satisfies the condition 1, 2, 3, 4 and test three satisfies conditions 1, 2, 3, 5. The test two results (Figure 15b) are the best fit for the simulation of stratiform precipitation.

The equation for the vertical distribution for the convective type of precipitation (e.g. Falcone models III and IV), is:

$$LWC = a * z^4 + b * z^3 + c * z^2 + d\,,$$

where

$$a = \frac{1}{z_m^5 z_t^2 - 2z_m^4 z_t^3 + z_m^3 z_t^4}\left[\left(3z_m z_t^2 - 2z_t^3 - z_m^3\right)m_s - \left(3z_m z_t^2 - 2z_t^3\right)m_m\right]$$

$$b = \frac{-1}{z_m^5 z_t^2 - 2z_m^4 z_t^3 + z_m^3 z_t^4}\left[\left(4z_m^2 z_t^2 - 2z_t^4 - 2z_m^4\right)m_s - \left(4z_m^2 z_t^2 - 2z_t^4\right)m_m\right]$$

$$c = \frac{-1}{z_m^4 z_t^2 - 2z_m^3 z_t^3 + z_m^2 z_t^4}\left[\left(z_m^4 - 4z_m z_t^3 + 3z_t^4\right)m_s + \left(4z_m z_t^3 - 3z_t^4\right)m_m\right]$$

$$d = m_s$$

Curves 3 and 4 in Figure 15a provide the vertical distribution for convective situations.

The equation for the stratiform type of precipitation (e.g. Falcone models I and II) is:

$$LWC = e * z^3 + f * z^2 + g * z + h\,,$$

where

$$e = \frac{-1}{z_m^2 z_t (z_t - z_m)^2}\left[(z_t - z_m)^2 m_s + z_t(2z_m - z_t)m_m\right]$$

$$f = \frac{-1}{z_m^2 z_t (z_t - z_m)^2}\left[(3z_m^2 z_t - z_t^3 - 2z_m^3)m_s - (3z_m^2 z_t - z_t^3)m_m\right]$$

$$g = \frac{-1}{z_m z_t (z_t - z_m)^2}\left[(z_m^3 - 3z_m z_t^2 + 2z_t^3)m_s + (3z_m z_t^2 - 2z_t^3)m_m\right]$$

$$h = m_s$$

Curves 1 and 2 in Figure 15b provide the vertical distribution for stratiform situations for different input parameters.

The vertical integrated liquid water content is:

$$ILWC = a/5 * Z_t^5 + b/4 * Z_t^4 + c/3 * Z_t^3 + e * Z_t + M_S$$

for the convective precipitation, and

$$ILWC = e/4 * Z_t^4 + f/3 * Z_t^3 + g/2 * Z_t^2 + h * Z_t + M_S$$

for the stratiform precipitation.

Some studies show that the height of the cloud top and the surface rainfall rate are closely related (Dennis et al., 1975). Thus we can derive the statistics of the relationship for different sites, and rewrite the cloud top as a function of the surface rainfall rate to derived a more precise vertical distribution of the liquid water field.

5.5 Summary

These studies reveal that the formation and evolution of hydrometers have close relationships with both microphysical and the dynamical processes. The inclusion of the ice-phase parameterization is important in simulating these processes.

Since the vertical distribution of the liquid and/or ice content is highly dependent on the type of the precipitation, the evolution stage of the thunderstorm, and the distance away from the core of the thunderstorm (in the area near the convection core or in the anvil area), a simple relationship between the surface rainfall rate and vertical liquid water distribution is quite site and time specific. A climatological record of the different sites should be collected and used to derive the simulation equation. The instant observation afforded by the satellite can be used to adjust some input parameters, e.g. cloud top and surface rainfall rate, which allow the simulation to be as close as possible to the real situation.

The specific simulated liquid water field can be obtained from the results of a numerical cloud model, however, this requires a significant amount of additional data. For this reason, we have adopted vertical profile models based on climatological models requiring a minimum of input data. The relationships provide a parameterization of vertical

hydrometeor liquid water content with surface rain rate and other input such as the height of the cloud and location and magnitude of the maximum. The latter are also provided by the Falcone et al. (1979) model classes.

6. CLOUD LIQUID WATER

Recognizing the difficulties associated with low correlations between SSM/I brightness temperatures and cloud liquid water content over land (and snow), the SSM/I calibration validation team recommended that retrievals of cloud liquid water not be attempted over land (Alishouse et al., 1988). In this study we have specifically undertaken to explore the parameterization of hydrometeor liquid water content vertical distribution and integrated amount for the purpose of characterizing intense convective activity. In the absence of other data sources (e.g. visible and infrared satellite data), some correlation can be inferred between precipitation events and cloud presence. To that extent, climatological cloud models can be applied in an attempt to characterize the cloud liquid water content based on SSM/I determination of the hydrometeor properties.

To this end we have adopted the cloud models proposed by Falcone et al. (1979) which accompany his respective precipitation event vertical profiles. A relationship between rainfall rate and cloud liquid water of the form:

$$M = 0.05 * RR ,$$

is proposed to provide a climatological cloud liquid water adjunct to the hydrometeor liquid water content discussed in the previous section. Following Falcone et al (1979), the vertical distribution of the cloud is assumed to have the same vertical dependence as the rain, except that its magnitude is scaled by the above relationship. Results for two sites, Tashkent and Perm are illustrated in Figures 16 and 17.

7. APPLICATION TO SELECTED PRECIPITATION EVENTS

In order to apply the liquid water content parameterizations for convective and stratiform situations defined in the previous sections, criteria had to be developed based on the mean areal rainfall rates and spatial standard deviation data available in the time series. This was accomplished by examining the ensemble properties of these two parameters for the four month study period using a simple clustering approach. The mean areal rainfall rates and spatial standard deviation for each site were plotted against one another. Results are given in Figures 18-28. These figures were plotted on the same scale so that comparisons can be made among the sites. Note that area averaging reduces local values considerably. Based on these cluster diagrams an approach was developed to differentiate between stratiform and convective precipitation regimes.

Notably there is a general similarity in the behavior of the cluster diagrams. Two regions are definable from the data. In the first region, there is a systemmatic increase of areal standard deviation with average rain rate. For some sites this increase is gradual and near linear (see Chita, Figure 20), while for other sites it is rapid and nonlinear (see Leningrad, Figure 22). The first region occupies the lower left quadrant of the available data. The second region occurs at higher rain rates and standard deviations than the first region, occupying more of the upper right quadrant of the data. The break points defining the transitions from region one to region two vary with site. Based on our examination of daily contours, we have defined region one to consist largely of stratiform events and region two to consist largely of convective events. There was not sufficient time in the study to provide detailed analyses to support this hypothesis. This should be explored using conventional data sources.

The implications of the categorization defined above based on examination of the cluster diagrams, is to provide criteria based on the rain rates and standard deviations to define membership in one of the clusters (i.e. either stratiform or convective) and then use

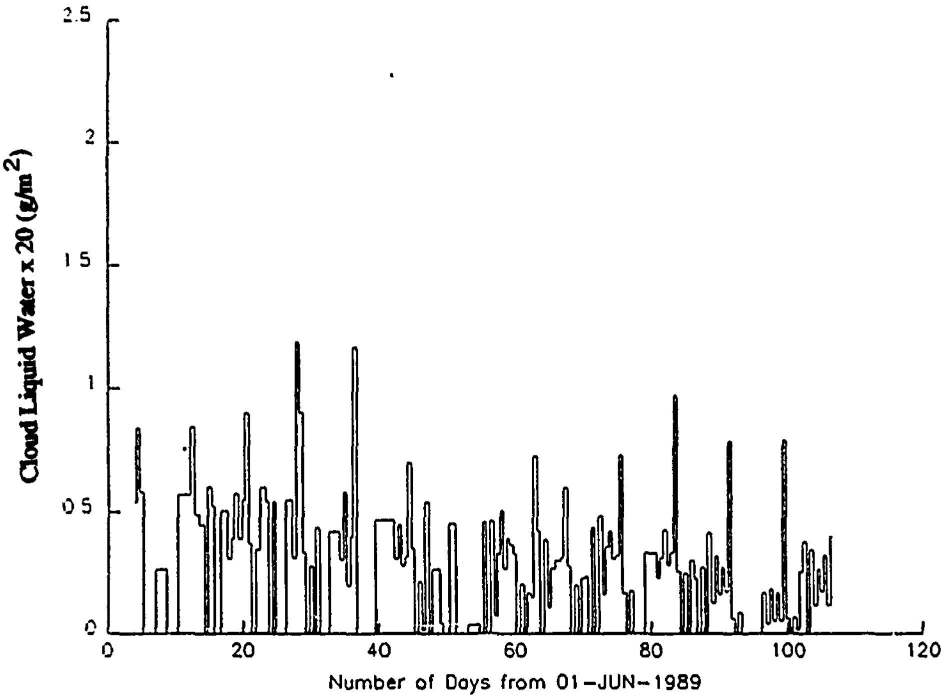

Figure 16. Cloud liquid water time series for Tashkent.

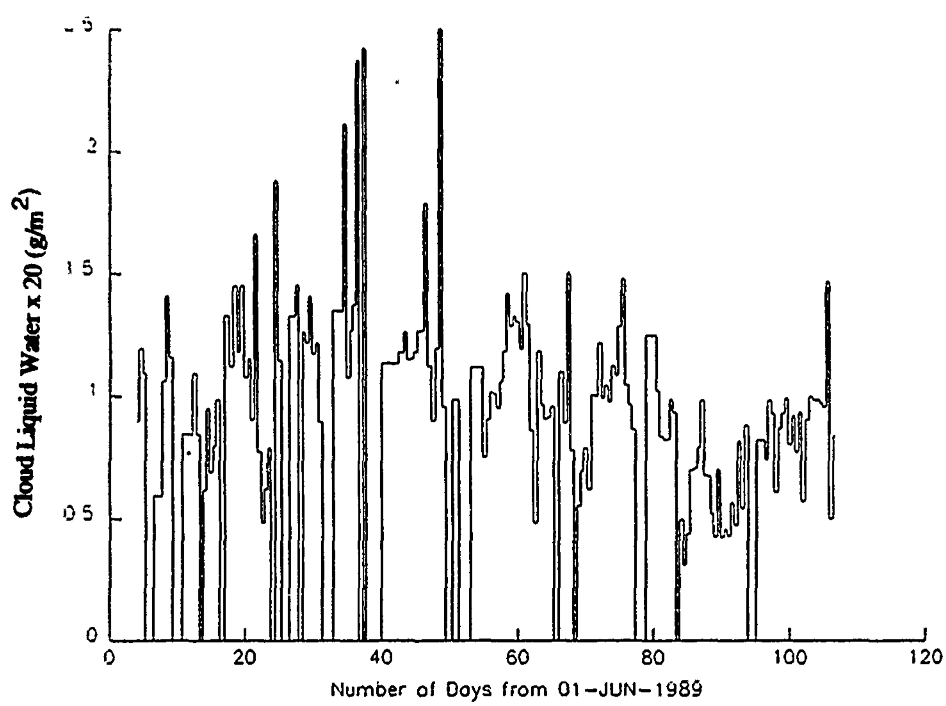

Figure 17. Cloud liquid water time series for Perm.

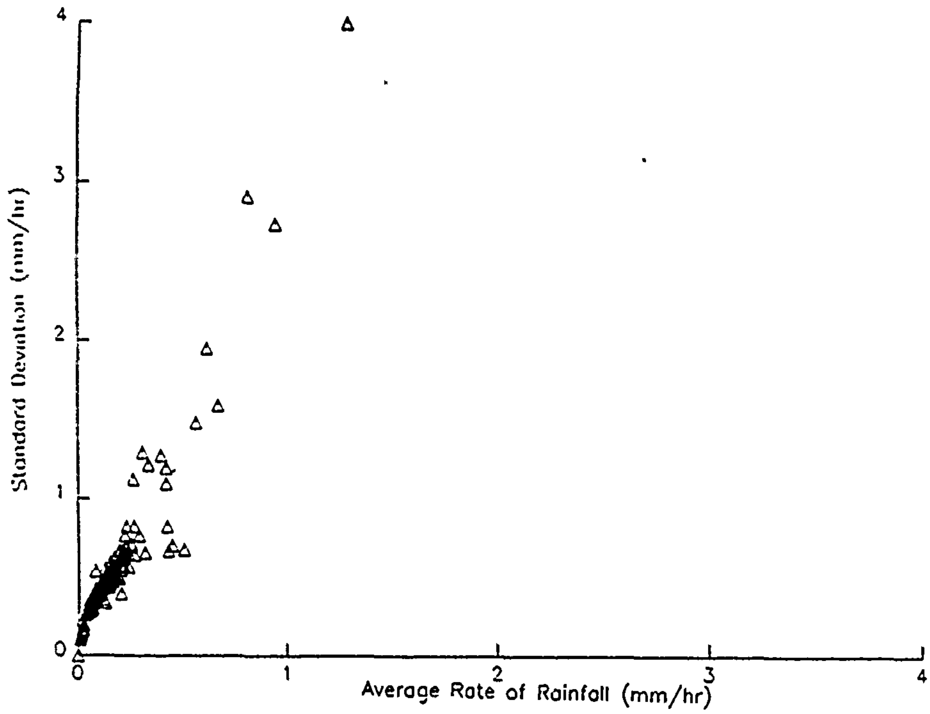

Figure 18. Cluster diagram for Aktyubinsk

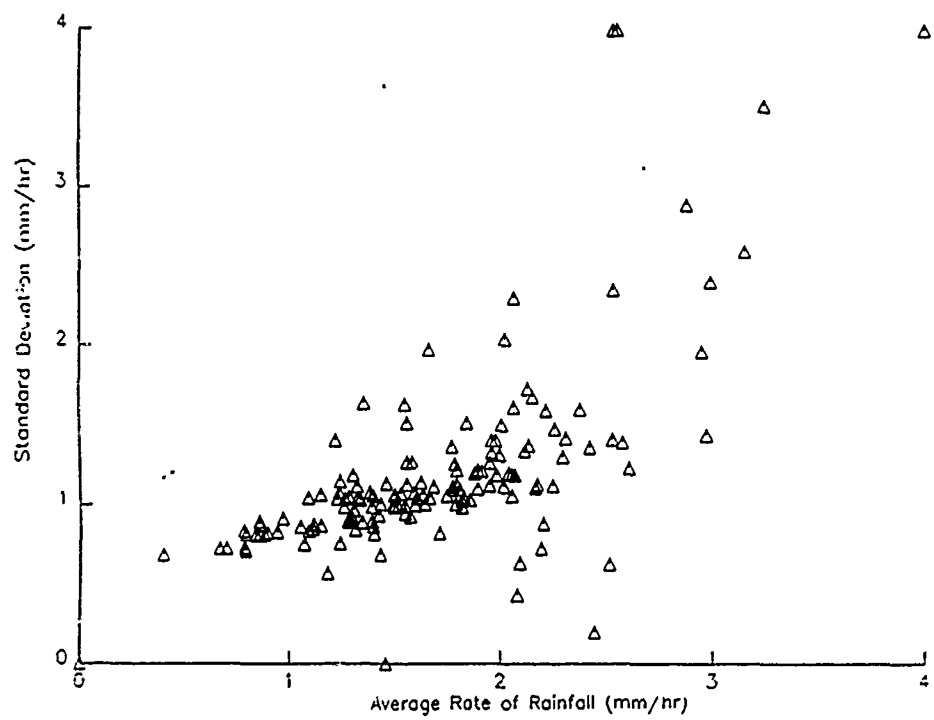

Figure 19. Cluster diagram for Blagoveschensk

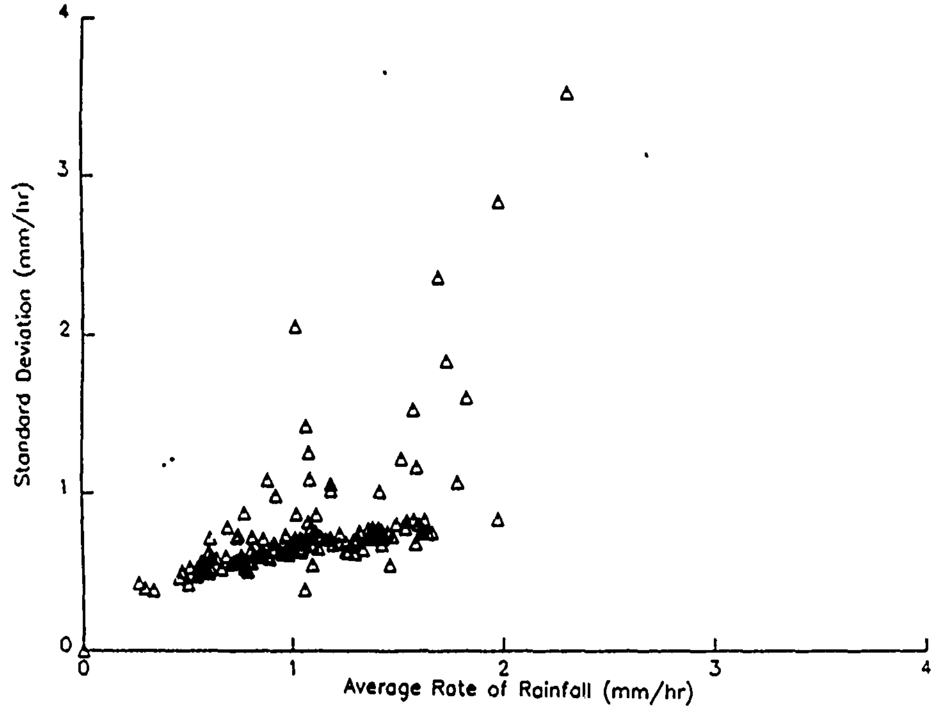

Figure 20. Cluster diagram for Chita

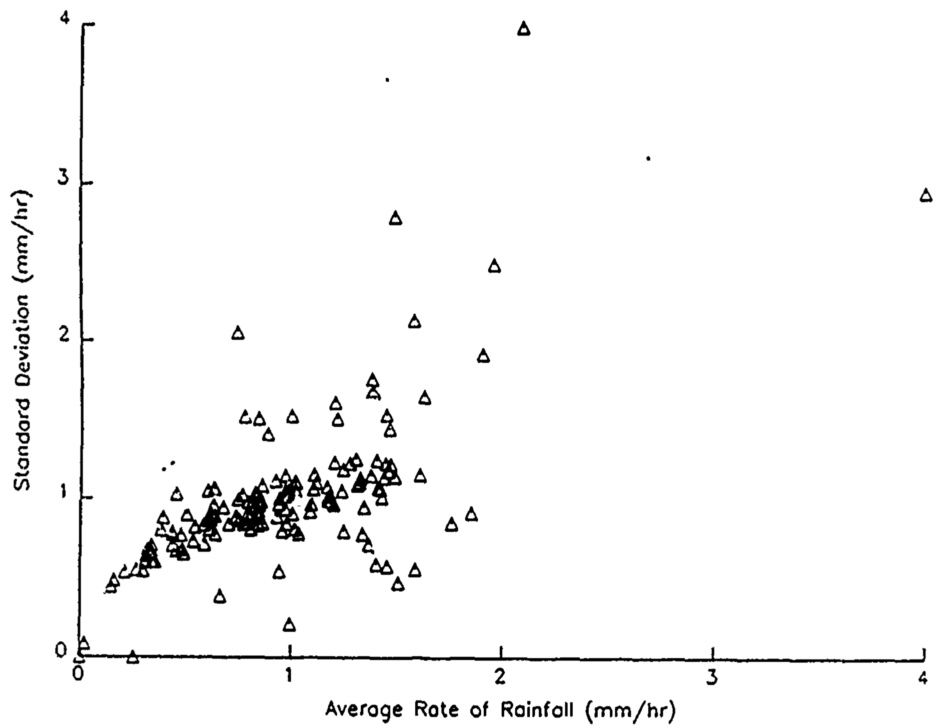

Figure 21. Cluster diagram for Kiev

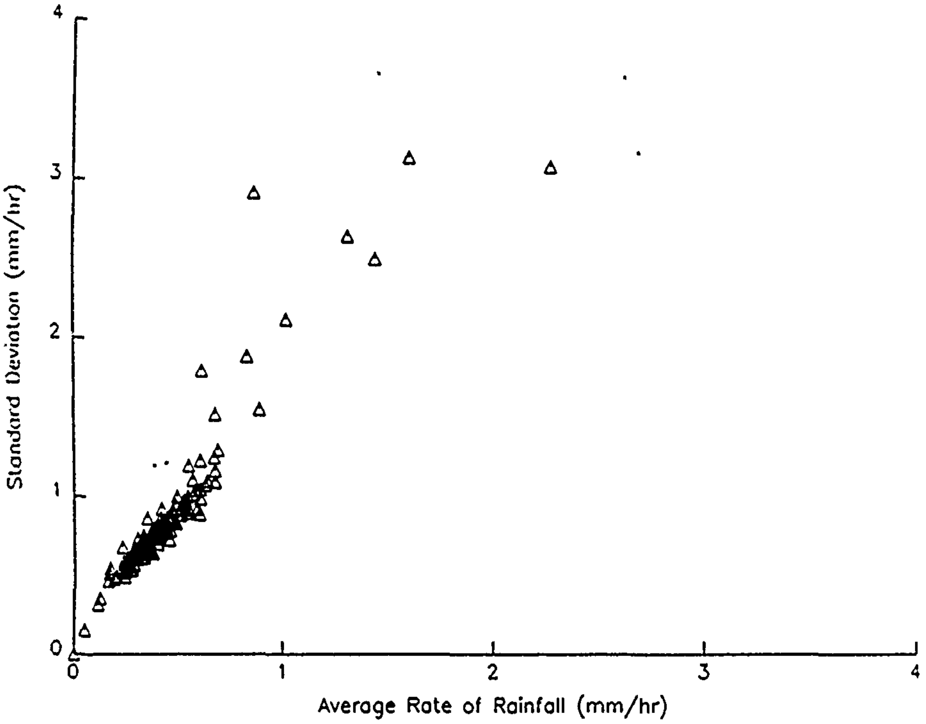

Figure 22. Cluster diagram for Leningrad

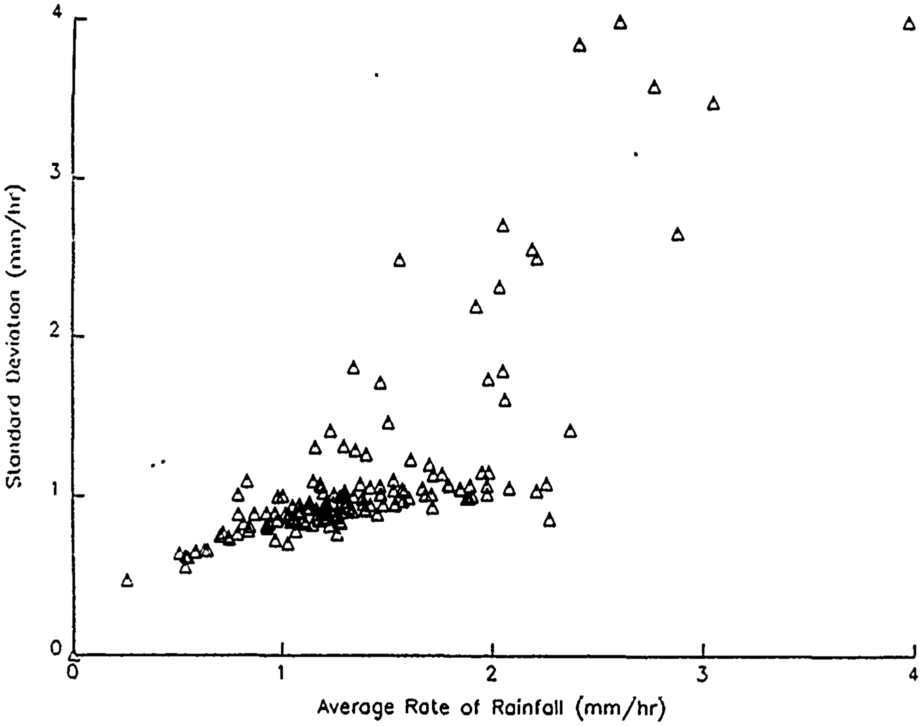

Figure 23. Cluster diagram for Moscow

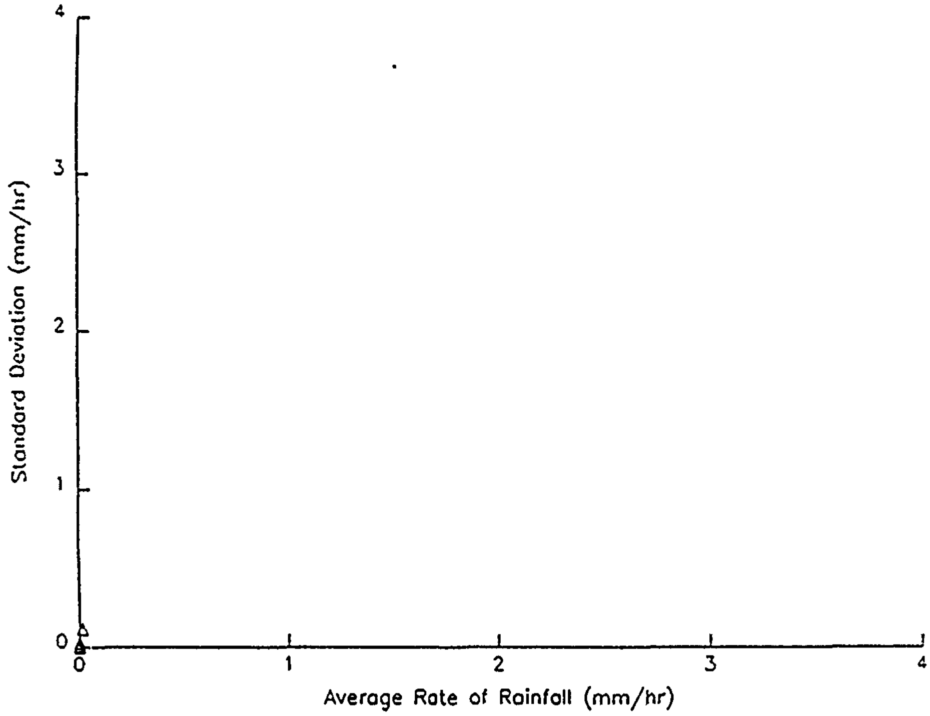

Figure 24. Cluster diagram for Murmansk

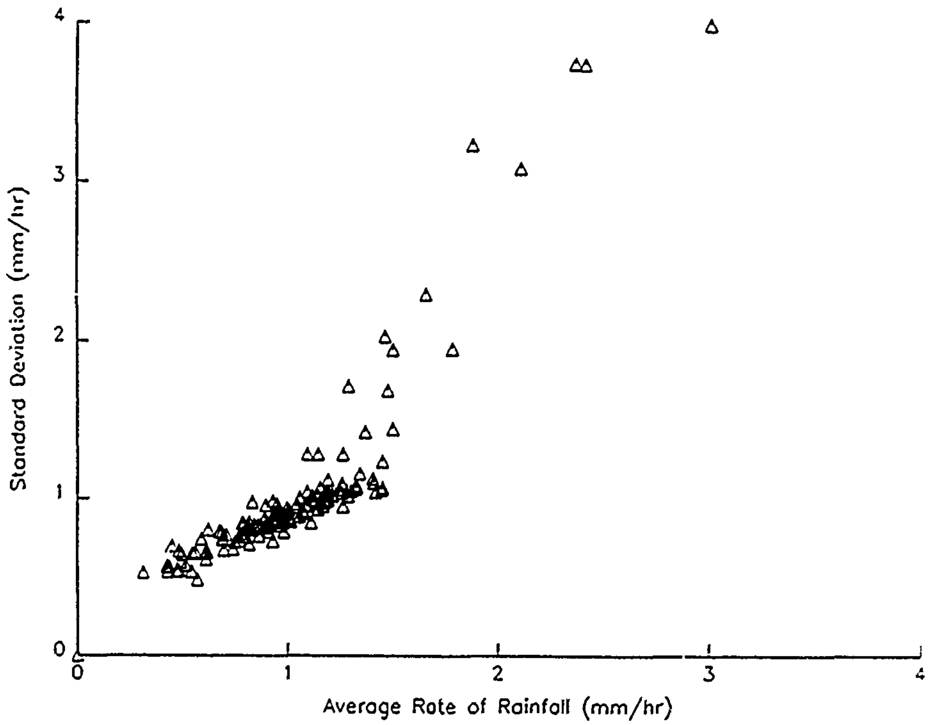

Figure 25. Cluster diagram for Perm

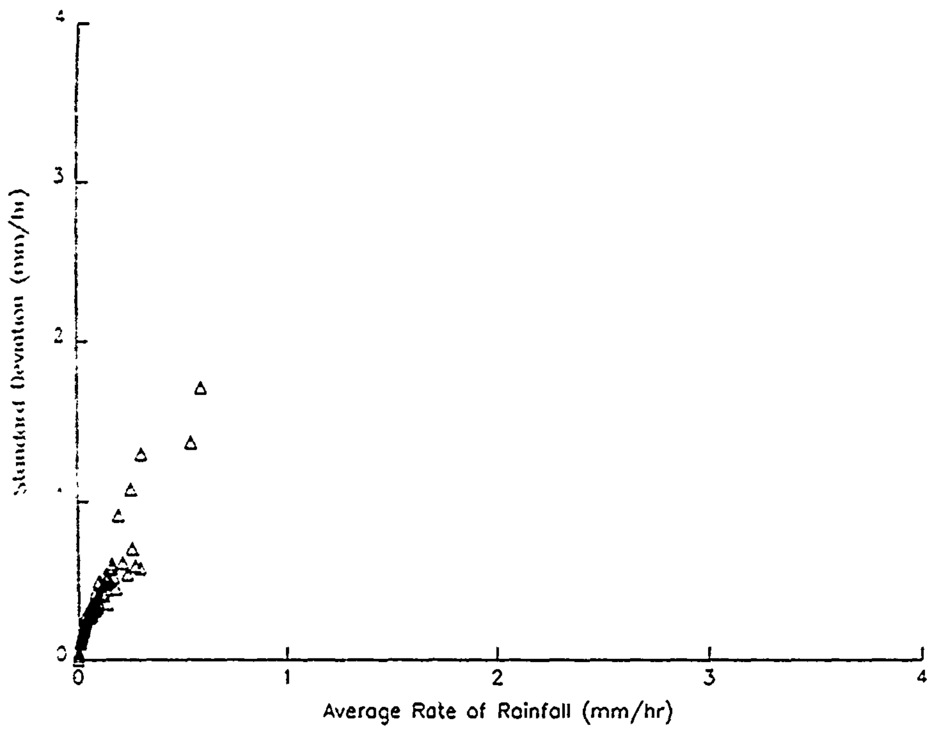

Figure 26. Cluster diagram for Semipalatinsk

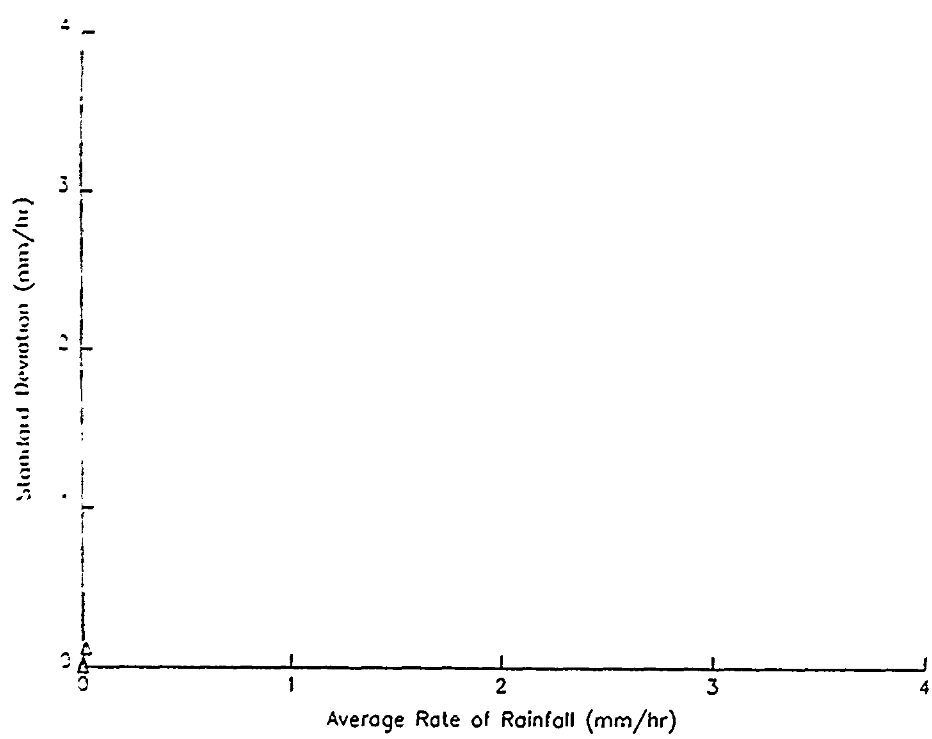

Figure 27. Cluster diagram for Simferopol

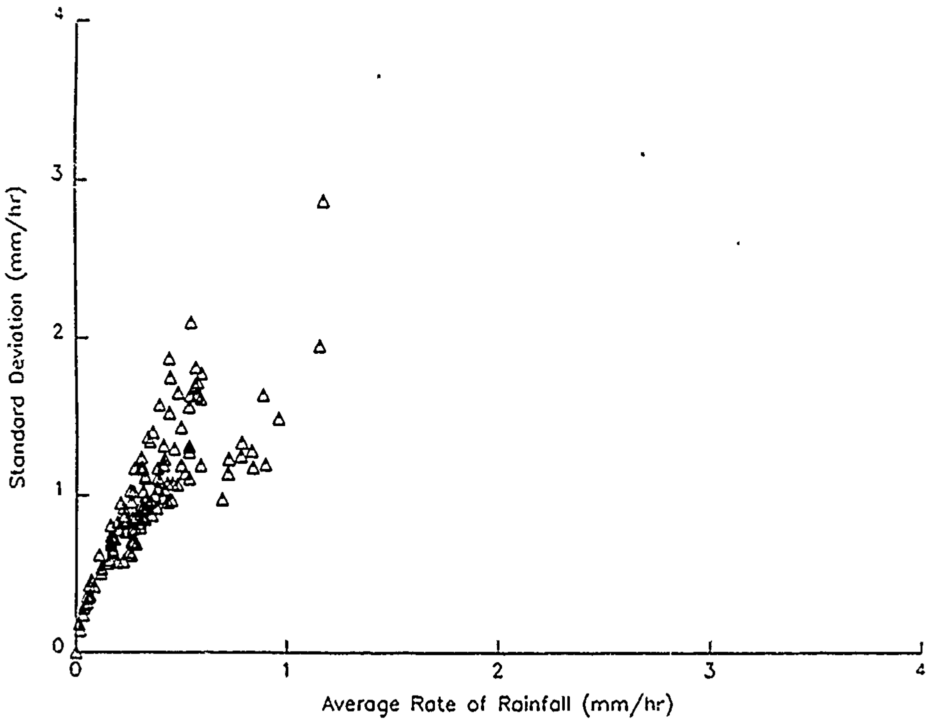

Figure 28. Cluster diagram for Tashkent

the appropriate liquid water content relationship developed in Section 5 to evaluate time series of this and related quantities for each site.

We have applied this approach to the data for Moscow displayed in Figure 23. The Moscow cluster diagram shows a region of low standard deviation days (SD < ~1.3) with increasing rain rate (region 1) bounded by high SD days. The highest SD days are those for which the rain rates are the highest. We have defined this latter cluster as region 2 in the context of the previous discussion. Therefore, the criteria adopted for this site is that days for which the SD is less than 1.3 are defined as stratiform and others are convective. The time series corresponding to application of this criterion for Moscow is shown in Figure 29a. For comparison, Figures 29b and 29c show the same time series when it is assumed that all precipitation events are stratiform or convective, respectively.

It should be noted that this criteria applies only to the Moscow time series and that a more general criteria for other sites has not been developed. Our approach would be to develop the generalized criteria based on normalized values using the mean average rainfall rate (i.e. the mean of the time series of areal averages) and mean standard deviation (i.e. the mean of the time series of spatial standard deviations).

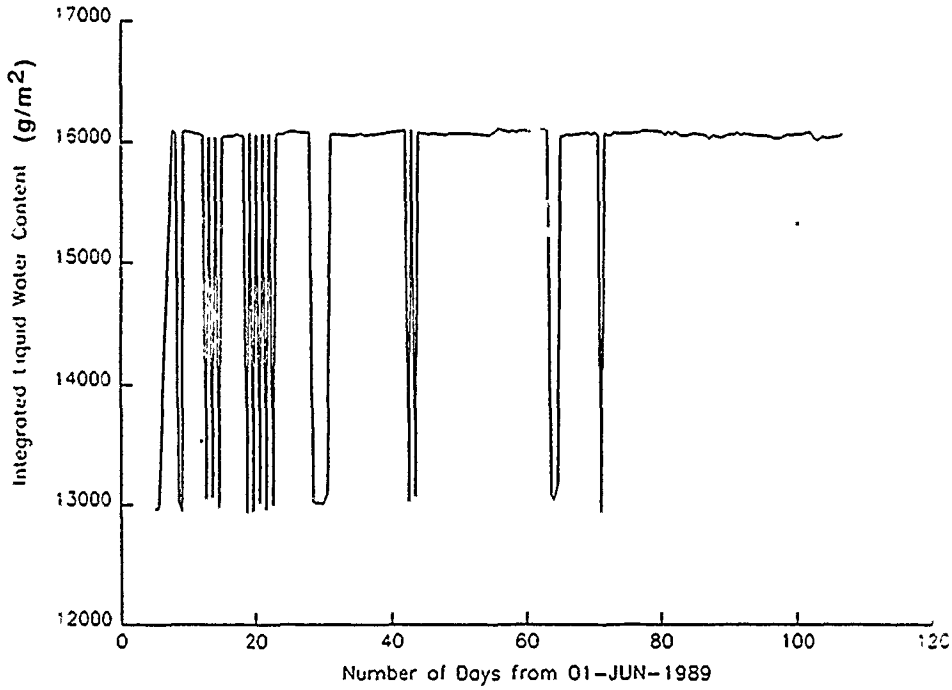

Figure 29a. Time series of ILWC for Moscow employing two region criteria

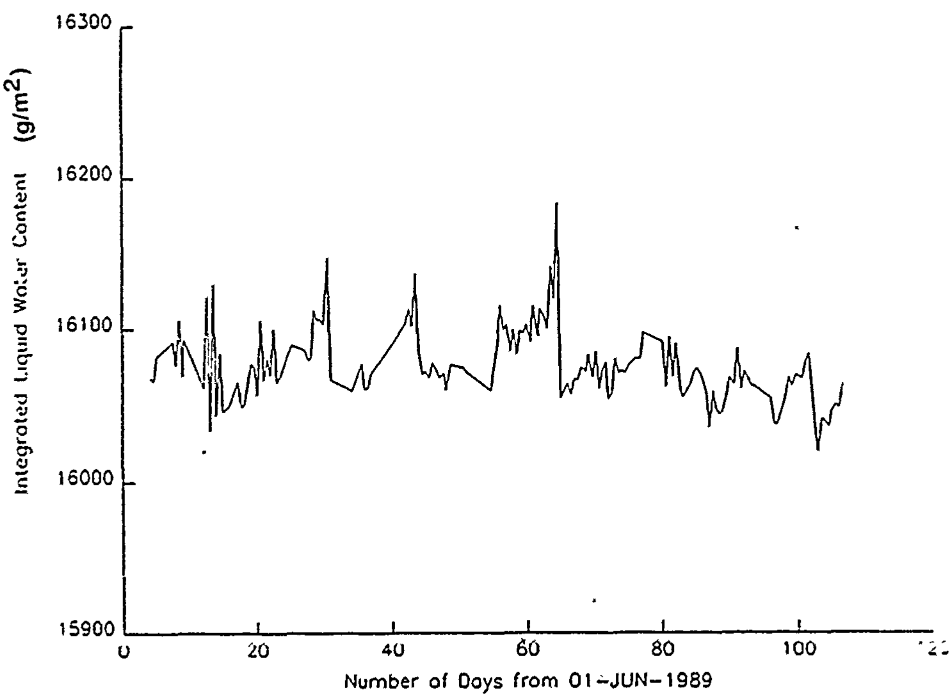

Figure 29b. Time series of ILWC for Moscow assuming stratiform only

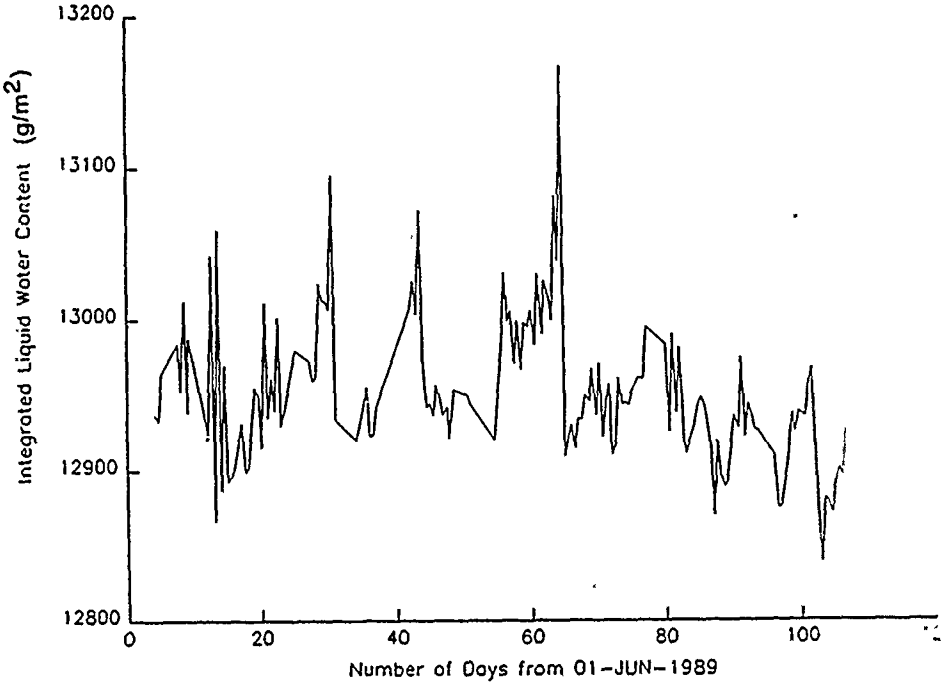

Figure 29c. Time series of ILWC for Moscow assuming convective only

To illustrate application of this approach to two additional sites the cluster diagrams were examined and Blagoveschensk and Leningrad (Figures 19 and 22, respectively) were selected. The cluster structure for Blagoveschensk is much more diffuse than for Moscow. There is a much greater variation in standard deviation which is qualitatively manifested in a much less organized stratiform arch. In this case we have based the definition of convective events on high average rainfall rate (> 1.5 mm/h) rather than on standard deviation as was done in the Moscow case. The results of applying this criterion for the determination of ILWC for the Blagoveschensk time series data are shown in Figures 30a-30c.

The cluster data for Leningrad exhibits yet another form of behavior. Rather than being diffuse as in the previous case, there is a very tight cluster of low rain rate/ low standard deviation near the origin with some outlying points of higher rain rate and standard deviation. We have defined the former class as stratiform events and the latter as convective. The results of applying these criteria for the determination of ILWC for the Leningrad time series data are shown in Figures 31a-31c.

8. CONCLUSIONS

This study has established the feasibility of establishing climatologies of stratiform and convective precipitation events for site specific regions of interests based on the use of SSM/I microwave imager brightness temperature data. The application of SSM/I microwave imager brightness temperature data to the determination of precipitation climatologies for eleven selected sites has been investigated. The SSM/I precipitation retrieval algorithm has been applied to the determination of surface rainfall rates within a 400 km region surrounding each site and additionally algorithms have been developed to provide areal averaged rain rates and spatial standard deviations. A novel application of the spatial standard deviations provides information on spatial inhomogeneities of the retrieved rain rates in addition to exploiting the spectral information content of the microwave brightness temperature data.

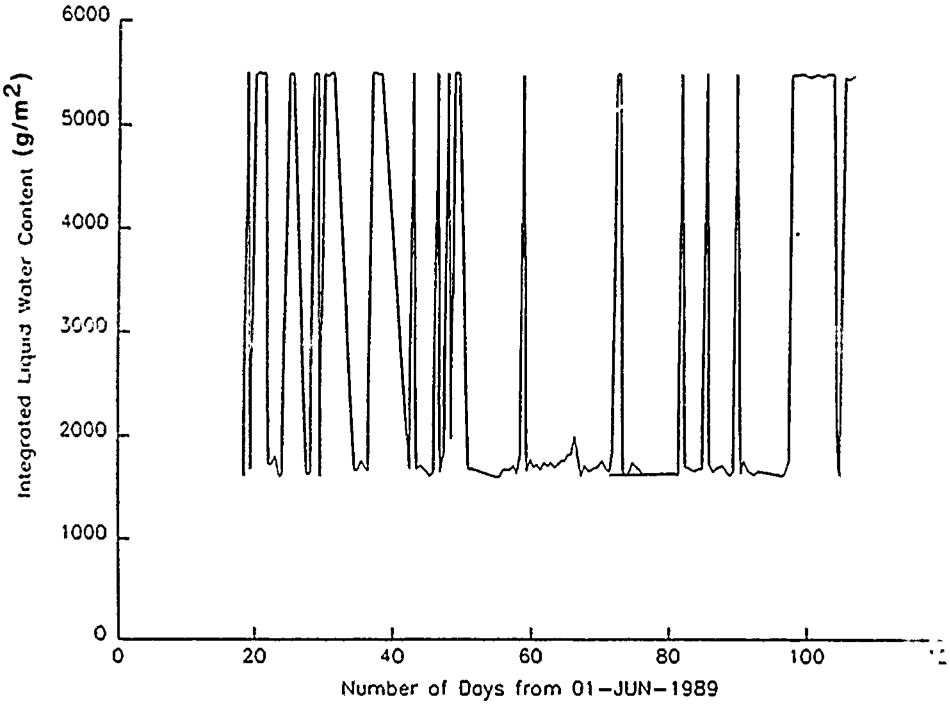

Figure 30a. Time series of ILWC for Blagoveschensk employing two region criteria

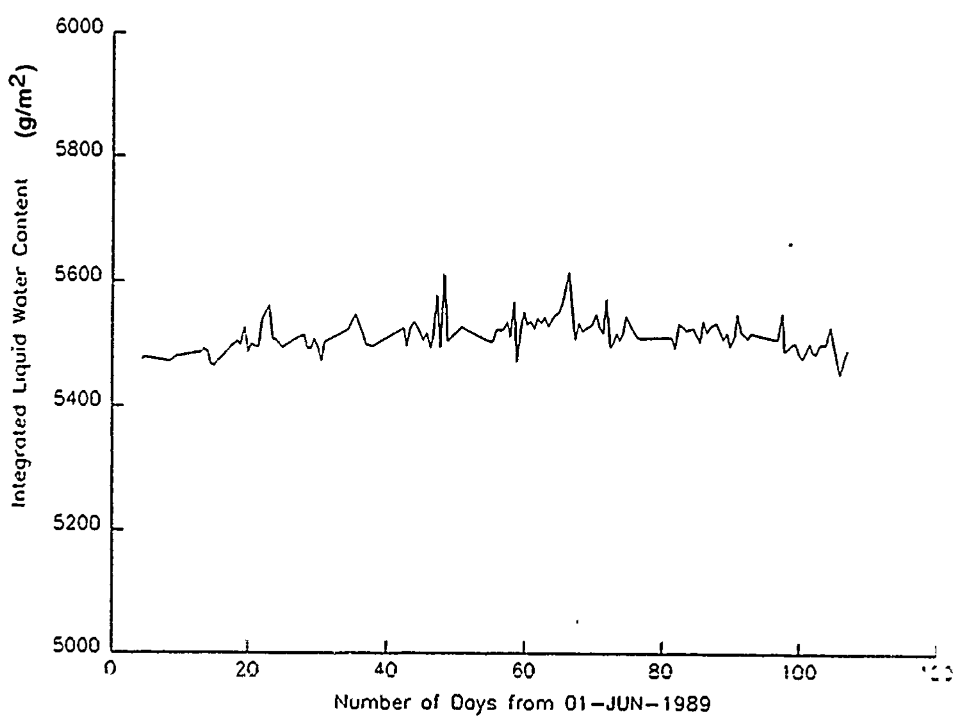

Figure 30b. Time series of ILWC for Blagoveschensk assuming stratiform only

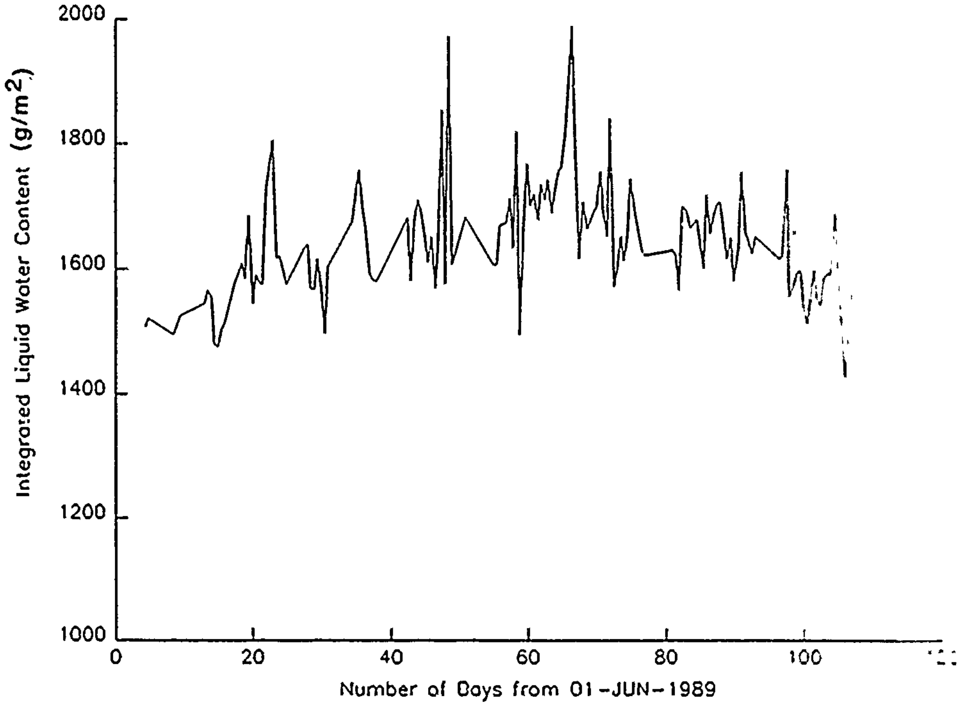

Figure 30c. Time series of ILWC for Blagoveschensk assuming convective only

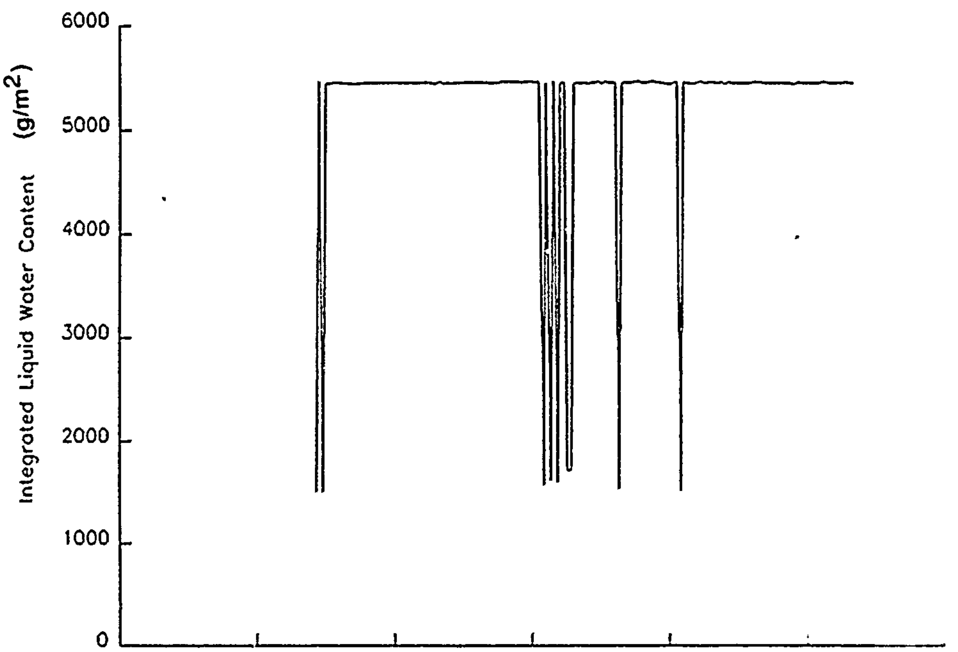

Figure 31a. Time series of ILWC for Leningrad employing two region criteria

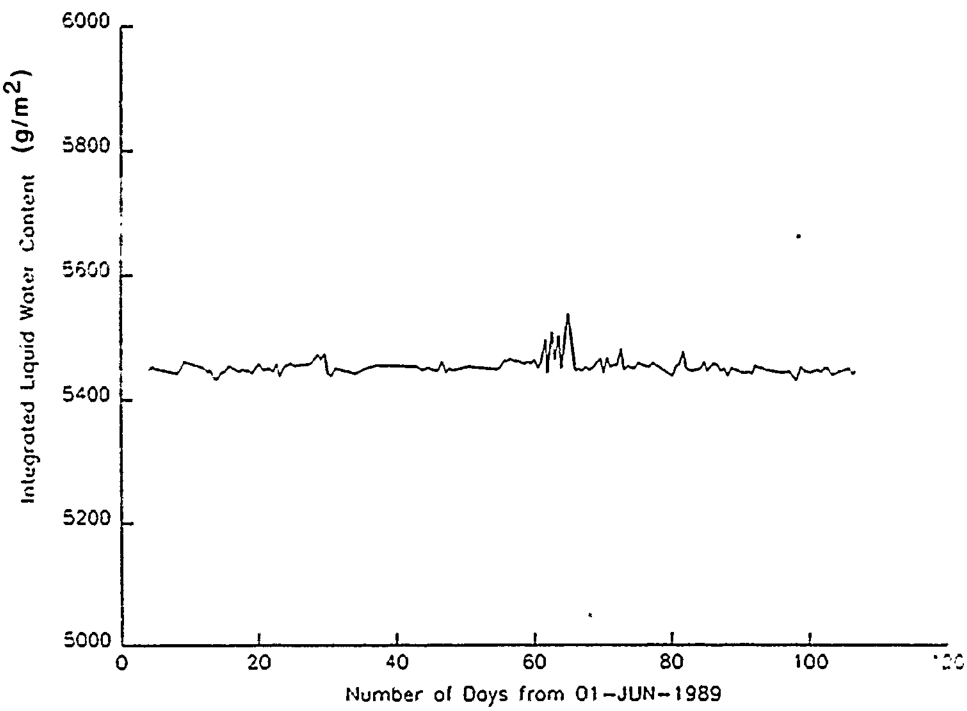

Figure 31b. Time series of ILWC for Leningrad assuming stratiform only

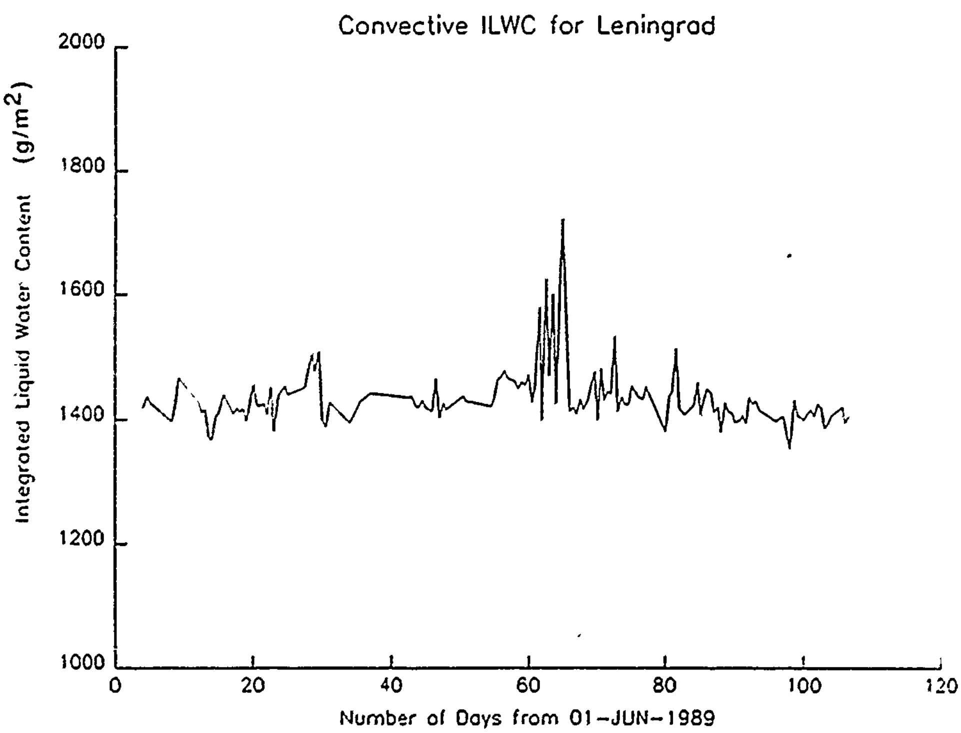

Figure 31c. Time series of ILWC for Leningrad assuming convective only

Time series of the areal averaged rain rates and spatial standard deviations have been calculated for a four month summer period for each of the sites. This climatology of precipitation events can be used to provide an indication of intense convective activity which is of interest in the determination of reentry vehicle erosion. In order to distinguish convective precipitation events, the areal averaged rainfall rates and standard deviations for each site have been displayed in cluster diagrams for the entire four month period. Based on these cluster diagrams, a set of preliminary criteria has been discussed to distinguish between stratiform and convective situations. Parameterizations of the vertical distributions of hydrometeor liquid water content for both stratiform and convective situations have been developed based on climatological precipitation cloud models. These parameterizations were developed after review of the relevant dynamical cloud model literature. Furthermore these vertical profiles of hydrometeor liquid water content have been integrated to provide functional relationships between SSM/I retrieved surface rain rates and total hydrometeor liquid water content. Time series of the total hydrometeor liquid water content have also been provided for selected sites.

It is recognized that cloud liquid water content profiles are also desired to calculate reentry vehicle erosion parameters. While cloud liquid water content is not directly retrievable over land based on the use of the SSM/I brightness temperature data, model based and climatological correlations between the vertical distribution of hydrometeor liquid water content and that of cloud liquid water content allows for a rudimentary characterization of cloud liquid water. A simple approach correlating hydrometeor and cloud liquid water vertical distributions has been explored based on climatological models available from the microwave attenuation literature. These models assume that the cloud liquid water content is proportional to the rainfall rate and that the shape of the vertical distribution of cloud liquid water is similar to that of the precipitation. Using this approach, time series of total cloud liquid water content is also provided for selected sites.

9. RECOMMENDATIONS

As proposed this study has focused exclusively on the use of SSM/I microwave imager brightness temperature data to develop rain rate climatologies. Precipitation events are indicative of meteorological situations which are inherently problematic with respect to reentry vehicle erosion. A novel aspect of the investigation is the application of spatial coherence concepts to the characterization of precipitation regimes such as stratiform and convective which determine the vertical distribution of hydrometeor liquid water content. Rain also acts as a surrogate for the presence of cloud which is not easily measured over land with microwave sensors.

A number of avenues of additional study are recommended based on the results reported here:

- More work should be done to exploit the identification of convective precipitation using the spatial information content of the microwave data. The examination of the spatial coherence properties of each site for the study period should be augmented with conventional observations to help in stratifying the observed arches and clusters according to the nature of the precipitation event. For example, surface and upper air data should be available from ETAC to be used in the analysis;

- As noted in Section 5 it is possible to identify numerical models of precipitation dynamics to support parameterization of rain rate/liquid water content relationships. In this study we resorted to climatological relationships for expediency. A fully interactive mesoscale model could be used as a vehicle for satellite data fusion and retrieval purposes;

- The algorithms developed here can be readily applied to the examination of alternate sites and changes in the statistical computations such as the time period and spatial

averaging field. Additionally, although bandpass limited by the inherent instantaneous fields-of-view of the SSM/I data, the spatial power spectrum of precipitation events could be determined. This would provide additional degrees of freedom beyond the simple measure provided by the spatial standard deviation;

- The clustering of rain rate and spatial standard deviations can be extended to use surface observations to further stratify the precipitation regime characterization. For example, frontal and various thunderstorm categories could be added along with their respective vertical distribution models. Available surface observations should also be employed to verify and validate the SSM/I time series. This was not investigated here;

- Data fusion with sensor data sources colocated aboard the DMSP spacecraft (OLS, SSM/T, SSM/T-2) should be investigated. Visible and infrared imagery provide a means to specify the presence of cloud, cloud cover, cloud type, and cloud top height. The evolution of multispectral imagery will provide the capability to identify high, middle, and low cloud in conjunction with nephanalysis techniques (d'Entremont, 1986). The use of microwave and millimeter wave sounder channels provides a means to sense the vertical distribution of liquid water content for precipitation analogous to the "slicing" approach for clouds employed using infrared sounder channels. The SSM/T microwave temperature sounder provides a signature in each channel which is proportional to the presence of precipitation elements at altitudes characteristic of its weighting function. Grasiewski and Staelin (1989) have suggested utilizing the impact of precipitation on microwave oxygen band (60GHz) and line (118GHz) absorption to obtain precipitation vertical structure information. An application of these concepts to the profiling of hydrometeor liquid water from DMSP SSM/T data could be fruitful in this regard. This would give a direct measurement which frees one from the climatological precipitation vertical distribution models employed in this study. The vertical distribution of cloud liquid water can then be obtained using the simple climatological based correlations suggested in this study;

- The SSM/T-2 moisture sounder is also sensitive to precipitation, however, due to its shorter wavelength response, it also provides a cloud liquid water signature (Isaacs and Deblonde, 1987). Although the number of available channels (five) is not as extensive as that potentially available from an infrared sounder, the millimeter wave channels respond to cloud liquid water content which can be directly related to cloud vertical structure and erosion parameter indices. The problem of high, variable surface emissivity inherent in the use of the SSM/I imager data is mitigated by the use of the SSM/T-2 sounder data. This is due to the vertical resolution properties of the sounding weighting functions which selectively sense the middle and upper tropospheric cloud liquid water (for increasingly absorbing channels of the sounder);

- Finally, it is recommended that the use of data available from civilian satellites including both the Tiros polar orbiters and the GOES geosynchronous platforms be investigated. Use of multispectral cloud imagery from the Tiros Advanced Very High Resolution Radiometer (AVHRR) can be used for multispectral nephanalysis. High resolution Infrared Sounder (HIRS) data can be used for applying the CO_2 slicing method. The GOES VAS (VISSR Atmospheric sounder) provides visible and infrared imagery and infrared sounder data. GOES infrared data could be particularly useful. The specific approach adopted could be modeled on that described by Adler and Negri, 1988). They used GOES imager data to delineate convective rain areas by searching for minima in the equivalent black body brightness temperature (EBBT) field and then assigned rain rates based on the results from a one dimensional cloud model which provided the relationship between convective development (cloud top height) and the resulting rain rate. Stratiform rain rates were delineated based on EBBT threshold criteria.

10. ACKNOWLEDGEMENT

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Appendix A SSM/I Data Extraction Software

```
C  PROGRAM NAME: RDSSMI.FOR                LAST UPDATE: 28FEB90
C  A USER FRIENDLY, GENERALIZED PROGRAM FOR READING FROM THE
C  WENTZ COMPRESSED SSM/I TAPES.
C  BEFORE RUNNING THE PROGRAM ISSUE THE FOLLOWING VAX COMMAND:
C
C     ALLOCATE HSC1$MUA0: FOR001:
C     MOUNT/FOREIGN/DENSITY=6250/BLOCKSIZE=28544/RECORDSIZE=1784
C                                FOR001:/COMMENT="TAPE XXXX"
C
C  QUESTIONS ABOUT THE PROGRAM?  CONTACT:
C                Mark Goodberlet
C                13 Marcus Hall
C                University of Massachusetts
C                Amherst, MA  01003
C                (413) 545-4675
C
      program rdssmi

      CHARACTER CSEL*1,IDUM

C**********************************
C     SPECIFY COMMON /INDATA/     *
C**********************************

      CHARACTER*1 LREC(1784)
      INTEGER*4 KBT,IBYT,IFLAG
      COMMON/INDATA/LREC,KBT,IBYT,IFLAG

      DATA KBT/1/      !Program set to work on VAX computer

   10 CONTINUE
      KFLAG=0

      WRITE(6,1000)
 1000 FORMAT(/'1'/23X,32('*')/
     &25X,'SSM/I DATA RETRIEVAL PROGRAM'/34X,
     &'MAIN MENU'/23X,32('*')//23X,
     &'C = EXTRACT SENSOR HEALTH DATA'/23X,
     &'B = EXTRACT TB AND WSP SWATH DATA'/23X,
     &'H = EXTRACT ALL 85GHZ TA DATA'/23X,
     &'Q = QUIT'//27X,'ENTER SELECTION <CR>: ',$)

      READ(5,1100)CSEL
 1100 FORMAT(A1)
      IF(CSEL .EQ. 'C' .OR. CSEL .EQ. 'c')CALL CALDAT(KFLAG)
      IF(CSEL .EQ. 'B' .OR. CSEL .EQ. 'b')CALL SWATH(1,KFLAG)
      IF(CSEL .EQ. 'H' .OR. CSEL .EQ. 'h')CALL SWATH(2,KFLAG)
      IF(CSEL .EQ. 'Q' .OR. CSEL .EQ. 'q')GO TO 999

C***********************************************************************
C  VARIABLE KFLAG INTERPRETATIONS                                      *
C       KFLAG=0 => INVALID OPTION SELECTED BY USER                     *
C       KFLAG=1 => SUCCESSFUL COMPLETION OF A USER SELECTED OPTION     *
C       KFLAG=2 => USER SELECTED A VALID OPTION NOT AVAILABLE AT THIS TIME *
C       KFLAG=3 => VALID OPTION SELECTED BUT EXECUTION ERROR ENCOUNTERED   *
C***********************************************************************

```

```
           IF(KFLAG .EQ. 0)WRITE(6,2100)
           IF(KFLAG .EQ. 2 .OR. KFLAG .EQ. 0)GO TO 10
           WRITE(6,2200)
           IF(KFLAG .EQ. 3) WRITE(6,2400)
      2100 FORMAT(/////21X,'INVALID SELECTION - PLEASE TRY AGAIN'//)
      2200 FORMAT(////////18X,'REWIND THE TAPE BEFORE RERUNNING THE PROGRAM'/
         &              19X,'    USE==> SET MAGTAPE/REWIND FOR001:     '////)
      2400 FORMAT(/23X,'*PROGRAM TERMINATED DUE TO ERRORS*')
       999 STOP
           END
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	242	PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $PDATA	431	PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL	48	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
3 INDATA	1796	PIC OVR REL GBL SHR NOEXE RD WRT QUAD
Total Space Allocated	2517	

ENTRY POINTS

Address	Type	Name
0-00000000		RDSSMI

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name	Address	Type	Name
2-00000000	CHAR	CSEL	3-000006FC	I*4	IBYT	2-00000001	CHAR	IDUM	3-00000700	I*4	IFLAG
3-000006F8	I*4	KBT	2-00000004	I*4	KFLAG						

ARRAYS

Address	Type	Name	Bytes	Dimensions
3-00000000	CHAR	LREC	1784	(1784)

LABELS

Address	Label	Address	Label	Address	Label	Address	Label	Address	Label	Address	Label
0-00000009	10	0-000000EB	999	1-00000008	1000'	1-000000E8	1100'	1-000000EB	2100'	1-0000011B	2200'
1-00000187	2400'										

```
FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name            Type  Name

        CALDAT                SWATH
```

```
0001      C**************************************
0002
```

COMMAND QUALIFIERS

```
  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ MAIN

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]MAIN.LIS;1
  /NOOBJECT
```

COMPILATION STATISTICS

```
  Run Time:           0.54 seconds
  Elapsed Time:       0.98 seconds
  Page Faults:        497
  Dynamic Memory:     344 pages
```

```
      SUBROUTINE CALDAT(KFLAG)

C*****************************************************************
C  PROGRAM USED TO STRIP SENSOR HEALTH DATA FROM THE WENTZ SSMI TAPES  *
C  NOTE:                                                           *
C       * ONLY A-SCAN CALIBRATION COUNTS ARE OUTPUTTED             *
C                                                                  *
C       * OTHER SENSOR HEALTH ITEMS AVAILABLE ARE:                 *
C             (1) AGC SETTINGS                                     *
C             (2) REF VOLTAGES 1 & 2                               *
C             (3) CALIB SLOPE VALUES                               *
C             (4) CALIB OFFSET VALUES                              *
C             (5) B-SCAN HOT AND COLD LOAD COUNTS                  *
C                                                                  *
C*****************************************************************

      INTEGER ITREF(7),ITNOW(7)
      INTEGER JULIAN(12,2),STIME,ETIME,HH,MM
      CHARACTER FNAME*10

C******************************
C     SPECIFY COMMON /INDATA/  *
C******************************

      CHARACTER*1 LREC(1784)
      INTEGER*4 KBT,IBYT,IFLAG
      COMMON/INDATA/LREC,KBT,IBYT,IFLAG

C*******************************
C     SPECIFY COMMON /OUTDAT/   *
C*******************************

      REAL*8 REV
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB,ISPAR1
      INTEGER*4 ITOIL,ISPAR2
      REAL*4 XLATSC,XLONSC,ALTSC,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI

      COMMON/OUTDAT/ REV,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),ISPAR1,
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),TAHI(8,64),ITOIL(4,64),ISPAR2(64)

      DATA ITREF/87,1,1,0,0,0,1/
      DATA JULIAN/1,32,60,91,121,152,182,213,244,274,305,335,
     &            1,32,61,92,122,153,183,214,245,275,306,336/

      OPEN(1,STATUS='OLD',BLOCKSIZE=28544,RECL=1784,
     & RECORDTYPE='FIXED',FORM='FORMATTED')

C*****************************
C  READ PAST THE TAPE HEADERS *
C*****************************

      CALL READHD
      WRITE(6,1000)
```

```
1000 FORMAT(1X/' ENTER START DATE (YR MM DD)(e.g. 88 1 25): ',$)
     READ(5,*)ITNOW(1),ITNOW(2),ITNOW(3)
     WRITE(6,1100)
1100 FORMAT(1X/' ENTER START TIME (HH MM SS)(e.g. 0 0 0): ',$)
     READ(5,*)ITNOW(4),ITNOW(5),ITNOW(6)
     CALL QTIME(ITREF,ITNOW,ITIME,IERR,1)
     STIME=ITIME
     WRITE(6,1200)
1200 FORMAT(1X/' ENTER END DATE (YR MM DD): ',$)
     READ(5,*)ITNOW(1),ITNOW(2),ITNOW(3)
     WRITE(6,1300)
1300 FORMAT(1X/' ENTER END TIME (HH MM SS): ',$)
     READ(5,*)ITNOW(4),ITNOW(5),ITNOW(6)
     CALL QTIME(ITREF,ITNOW,ITIME,IERR,1)
     ETIME=ITIME
     WRITE(6,1400)
1400 FORMAT(1X/' ENTER OUTPUT FILE NAME: '$)
     READ(5,1500)FNAME
1500 FORMAT(A10)
     OPEN(UNIT=2,STATUS='NEW',NAME=FNAME)

C**********************************
C  WRITE HEADERS TO THE OUTPUT FILE *
C**********************************

     WRITE(2,1600)
1600 FORMAT(' OUTPUT LINE #1==> SCAN TIME, 3 HOT LOAD TEMPS,',
    &' RF MIXER TEMP, AND FWD RADIATOR TEMP'/
    &' OUTPUT LINE #2==> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 19V'/
    &' OUTPUT LINE #3==> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 19H'/
    &' OUTPUT LINE #4==> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 37V'/
    &' OUTPUT LINE #5==> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 37H'/
    &' OUTPUT LINE #6==> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 22V'/
    &' OUTPUT LINE #7==> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 85V'/
    &' OUTPUT LINE #8==> FIVE COLD LOAD AND HOT LOAD COUNTS FOR 85H')
     IREC=0
     IREC2=0
     WRITE(6,1800)
1800 FORMAT(///'      REC NO')
  10 IEOF=0
  11 READ(1,2000,END=12)LREC
2000 FORMAT(1784A1)
     GO TO 14
  12 IEOF=IEOF+1
     WRITE(6,2001)IEOF
2001 FORMAT(' IEOF= ',I2)

C*****************************************
C  DOUBLE END-OF-FILE MEANS END-OF-TAPE   *
C*****************************************

     IF(IEOF .EQ. 2)GO TO 999
     GO TO 11
  14 CONTINUE
     IREC=IREC+1
     IREC2=IREC2+1
     IF(IREC.EQ.25)WRITE(6,*)IREC2
```

```
          IF(IREC.EQ.25)IREC=0
          ITIME=INT44(KBT,LREC(1),LREC(2),LREC(3),LREC(4))
          CALL QTIME(ITREF,ITNOW,ITIME,IERR,2)
          JDAY=JULIAN(ITNOW(2),ITNOW(7))+ITNOW(3)-1
          HH=ITNOW(4)
          MM=ITNOW(5)
          REV=1.D-4*INT44(KBT,LREC(5),LREC(6),LREC(7),LREC(8))
          IF(ITIME.LT.STIME)GO TO 10
          IF(ITIME.GT.ETIME)GO TO 999
          CALL FDCAL
          WRITE(2,2100)JDAY,HH,MM,(HLTEMP(I),I=1,3),RFTEMP,FRTEMP
          DO 50 JCH=1,7
            WRITE(2,2200)(ICOLDA(I,JCH),I=1,5),(IHOTA(I,JCH),I=1,5)
       50 CONTINUE
     2100 FORMAT(' ',I3,X,I2,X,I2,5(X,F7.2))
     2200 FORMAT(' ',5(I5,X),5X,5(I5,X))
          GO TO 10
      999 KFLAG=1
          RETURN
          END
```

```
PROGRAM SECTIONS

    Name                                    Bytes   Attributes

  0 $CODE                                     906   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  1 $PDATA                                    834   PIC CON REL LCL   SHR NOEXE   RD NOWRT QUAD
  2 $LOCAL                                    488   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD
  3 INDATA                                   1796   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD
  4 OUTDAT                                   7156   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD

    Total Space Allocated                   11180

ENTRY POINTS

    Address  Type  Name

  0-00000000       CALDAT

VARIABLES

    Address  Type  Name               Address  Type  Name               Address  Type  Name               Address  Type  Name

  4-00000018  R*4  ALTSC           2-000000A8  I*4  ETIME           2-00000098  CHAR FNAME           4-00000034  R*4  FRTEMP
  2-000000AC  I*4  HH              2-000000C8  I*4  I               3-000006FC  I*4  IBYT            2-000000C0  I*4  IEOF
  2-000000B4  I*4  IERR            3-00000700  I*4  IFLAG           2-000000B8  I*4  IREC            2-000000BC  I*4  IREC2
  4-000001F0  I*4  ISPAR1          4-00000008  I*4  ITIME           4-0000000C  I*4  ITIMSC          2-000000CC  I*4  JCH
  2-000000C4  I*4  JDAY            3-000006F8  I*4  KBT            AP-00000004@ I*4  KFLAG           2-000000B0  I*4  MM
  4-00000000  R*8  REV             4-00000030  R*4  RFTEMP          2-000000A4  I*4  STIME           4-00000010  R*4  XLATSC
  4-00000014  R*4  XLONSC
```

ARRAYS

Address	Type	Name	Bytes	Dimensions
4-000001F4	R*4	ALAT	512	(128)
4-000003F4	R*4	ALON	512	(128)
4-000005F4	R*4	BLAT	512	(128)
4-000007F4	R*4	BLON	512	(128)
4-0000006C	R*4	CALOFF	28	(7)
4-00000050	R*4	CALSLP	28	(7)
4-0000001C	R*4	HLTEMP	12	(3)
4-00000038	I*4	IAGC	24	(6)
4-00000088	I*4	ICOLDA	140	(5, 7)
4-000001A0	I*4	ICOLDB	40	(5, 2)
4-00000114	I*4	IHOTA	140	(5, 7)
4-000001C8	I*4	IHOTB	40	(5, 2)
4-00001AF4	I*4	ISPAR2	256	(64)
2-0000001C	I*4	ITNOW	28	(7)
4-000016F4	I*4	ITOIL	1024	(4, 64)
2-00000000	I*4	ITREF	28	(7)
4-00000028	I*4	IVOLT	8	(2)
2-00000038	I*4	JULIAN	96	(12, 2)
3-00000000	CHAR	LREC	1784	(1784)
4-00000EF4	R*4	TAHI	2048	(8, 64)
4-000009F4	R*4	TALO	1280	(5, 64)

LABELS

Address	Label	Address	Label	Address	Label	Address	Label	Address	Label	Address	Label
0-000001BD	10	0-000001C0	11	0-000001E7	12	0-00000215	14	0-0000037D	50	0-00000385	999
1-00000008	1000'	1-0000003B	1100'	1-0000006C	1200'	1-0000008F	1300'	1-000000B2	1400'	1-000000D2	1500'
1-000000D5	1600'	1-000002EE	1800'	1-00000300	2000'	1-00000306	2001'	1-00000312	2100'	1-0000032A	2200'

FUNCTIONS AND SUBROUTINES REFERENCED

Type	Name	Type	Name	Type	Name	Type	Name	Type	Name
	FDCAL		FOR$OPEN	I*4	INT44		QTIME		READHD

```
0001      C************************************
0002
0003
```

COMMAND QUALIFIERS

```
  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ CALDAT

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]CALDAT.LIS;1
  /NOOBJECT
```

COMPILATION STATISTICS

```
  Run Time:          1.35 seconds
  Elapsed Time:      4.32 seconds
  Page Faults:       293
  Dynamic Memory:    400 pages
```

```
      subroutine estreg (regions)
C*****************************************************************
C  Subroutine ESTREG establishes the coordinates of 11 Eurasian sites  *
C  in a 2-D array.  This is a specific example.  This routine can be   *
C  easily modified to accept user-defined locations.                   *
C                                                                      *
C  The first dimension of the 2-D array refers to the location in      *
C  question.  The ordering is as follows:  (east longitudes!)          *
C                                                                      *
C      1 = Lenigrad                                                    *
C      2 = Kiev                                                        *
C      3 = Simferopol                                                  *
C      4 = Moscow                                                      *
C      5 = Murmansk                                                    *
C      6 = Perm                                                        *
C      7 = Aktyubinsk                                                  *
C      8 = Tashkent                                                    *
C      9 = Semipalatinsk                                               *
C     10 = Chita                                                       *
C     11 = Blagoveschensk                                              *
C                                                                      *
C*****************************************************************

      real regions(11,4), box(4)

C***************
C  Leningrad   *
C***************
      call geobox (59.96, 30.30, 200.00, box)
      regions(1,1) = box(1)
      regions(1,2) = box(2)
      regions(1,3) = box(3)
      regions(1,4) = box(4)

C**********
C  Kiev   *
C**********
      call geobox (50.40, 30.45, 200.00, box)
      regions(2,1) = box(1)
      regions(2,2) = box(2)
      regions(2,3) = box(3)
      regions(2,4) = box(4)

C****************
C  Simferopol   *
C****************
      call geobox (45.01, 33.98, 200.00, box)
      regions(3,1) = box(1)
      regions(3,2) = box(2)
      regions(3,3) = box(3)
      regions(3,4) = box(4)

C************
C  Moscow   *
C************
      call geobox (55.96, 37.41, 200.00, box)
      regions(4,1) = box(1)
```

```
        regions(4,2) = box(2)
        regions(4,3) = box(3)
        regions(4,4) = box(4)

C***************
C   Murmansk    *
C***************
        call geobox (68.96, 33.05, 200.00, box)
        regions(5,1) = box(1)
        regions(5,2) = box(2)
        regions(5,3) = box(3)
        regions(5,4) = box(4)

C***********
C   Perm   *
C***********
        call geobox (58.01, 56.30, 200.00, box)
        regions(6,1) = box(1)
        regions(6,2) = box(2)
        regions(6,3) = box(3)
        regions(6,4) = box(4)

C*****************
C   Aktyubinsk   *
C*****************
        call geobox (50.28, 57.15, 200.00, box)
        regions(7,1) = box(1)
        regions(7,2) = box(2)
        regions(7,3) = box(3)
        regions(7,4) = box(4)

C***************
C   Tashkent    *
C***************
        call geobox (41.26, 69.26, 200.00, box)
        regions(8,1) = box(1)
        regions(8,2) = box(2)
        regions(8,3) = box(3)
        regions(8,4) = box(4)

C********************
C   Semipalatinsk    *
C********************
        call geobox (50.35, 80.25, 200.00, box)
        regions(9,1) = box(1)
        regions(9,2) = box(2)
        regions(9,3) = box(3)
        regions(9,4) = box(4)

C************
C   Chita    *
C************
        call geobox (52.01, 113.33, 200.00, box)
        regions(10,1) = box(1)
        regions(10,2) = box(2)
        regions(10,3) = box(3)
        regions(10,4) = box(4)
```

```
C*********************
C   Blagovoschensk    *
C*********************
          call geobox (50.26, 127.50, 200.00, box)
          regions(11,1) = box(1)
          regions(11,2) = box(2)
          regions(11,3) = box(3)
          regions(11,4) = box(4)

          return
          end
```

```
PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                   511   PIC CON REL LCL   SHR   EXE    RD NOWRT QUAD
  1 $PDATA                                   92   PIC CON REL LCL   SHR NOEXE    RD NOWRT QUAD
  2 $LOCAL                                  280   PIC CON REL LCL NOSHR NOEXE    RD   WRT QUAD

    Total Space Allocated                   883


ENTRY POINTS

    Address   Type  Name

  0-00000000        ESTREG


ARRAYS

    Address   Type  Name                Bytes  Dimensions

  2-00000000  R*4   BOX                    16  (4)
 AP-00000004@ R*4   REGIONS               176  (11, 4)


FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name

        GEOBOX
```

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ ESTREG

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]ESTREG.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:            1.08 seconds
  Elapsed Time:        1.55 seconds
  Page Faults:         514
  Dynamic Memory:      392 pages
```

```
      SUBROUTINE FDCAL

      INTEGER*4 IBH,IBC
      REAL*4 SCALE1(10)

C*************************************
C     SPECIFY COMMON /INDATA/         *
C*************************************

      CHARACTER*1 LREC(1784)
      INTEGER*4 KBT,IBYT,IFLAG
      COMMON/INDATA/LREC,KBT,IBYT,IFLAG

C*************************************
C     SPECIFY COMMON /OUTDAT/         *
C*************************************

      REAL*8 REV
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB,ISPAR1
      INTEGER*4 ITOIL,ISPAR2
      REAL*4 XLATSC,XLONSC,ALTSC,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI

      COMMON/OUTDAT/ REV,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),ISPAR1,
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),TAHI(8,64),ITOIL(4,64),ISPAR2(64)

C***************************
C     DATA INITIALIZATION   *
C***************************

      DATA SCALE1/3*1.E-2,2*1.,2*1.E-2,3*1./

C**********************
C     BEGIN EXECUTION  *
C**********************

      ITIME=INT44(KBT,LREC(1),LREC(2),LREC(3),LREC(4))
      REV=1.D-4*INT44(KBT,LREC(5),LREC(6),LREC(7),LREC(8))
      ITIMSC=INT44(KBT,LREC(9),LREC(10),LREC(11),LREC(12))
      XLATSC=1.D-6*INT44(KBT,LREC(13),LREC(14),LREC(15),LREC(16))-90.
      ISPAR1=INT44(KBT,LREC(17),LREC(18),LREC(19),LREC(20))
      XLONSC=1.D-6*INT44(KBT,LREC(21),LREC(22),LREC(23),LREC(24))
      ALTSC=1.D-3*INT44(KBT,LREC(25),LREC(26),LREC(27),LREC(28))
      IBYT=29

      DO 100 IP=1,3
         HLTEMP(4-IP)=0.01*INT24(KBT,LREC(IBYT),LREC(IBYT+1))
         IBYT=IBYT+2
  100 CONTINUE

      IVOLT(2)=INT24(KBT,LREC(35),LREC(36))
      IVOLT(1)=INT24(KBT,LREC(37),LREC(38))
      RFTEMP=0.01*INT24(KBT,LREC(39),LREC(40))
      FRTEMP=0.01*INT24(KBT,LREC(41),LREC(42))
```

```
      IBYT = 43

      DO 200 IP=8,10
         IAGC(11-IP)=INT24(KBT,LREC(IBYT),LREC(IBYT+1))
         IBYT=IBYT+2
  200 CONTINUE

      DO 300 ICH=1,7
         CALSLP(ICH)=1.E-5*INT24(KBT,LREC(IBYT),LREC(IBYT+1))
         CALOFF(ICH)=2.E-2*INT24(KBT,LREC(IBYT+2),LREC(IBYT+3))
         IBYT=IBYT+4
  300 CONTINUE

      IBC=IBYT
      IBH=IBYT+70
      DO 400 ICH=1,7
      DO 400 IP=1,5
         ICOLDA(IP,ICH)=INT24(KBT,LREC(IBC),LREC(IBC+1))
         IHOTA(IP,ICH)=INT24(KBT,LREC(IBH),LREC(IBH+1))
         IBC=IBC+2
         IBH=IBH+2
  400 CONTINUE
      IBYT=IBH

      DO 500 IP=1,3
         IAGC(7-IP)=INT24(KBT,LREC(IBYT),LREC(IBYT+1))
         IBYT=IBYT+2
  500 CONTINUE
      IBC=IBYT
      IBH=IBYT+20

      DO 600 ICH=1,2
      DO 600 IP=1,5
         ICOLDB(IP,ICH)=INT24(KBT,LREC(IBC),LREC(IBC+1))
         IHOTB(IP,ICH)=INT24(KBT,LREC(IBH),LREC(IBH+1))
         IBC=IBC+2
         IBH=IBH+2
  600 CONTINUE
      IBYT=IBH

      RETURN
      END
```

```
PROGRAM SECTIONS

    Name                                     Bytes   Attributes

  0 $CODE                                      956   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                     864   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD
  3 INDATA                                    1796   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD
  4 OUTDAT                                    7156   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD

    Total Space Allocated                    10772

ENTRY POINTS

    Address   Type  Name

  0-00000000        FDCAL

VARIABLES

    Address   Type  Name              Address   Type  Name              Address   Type  Name              Address   Type  Name

  4-00000018  R*4   ALTSC           4-00000034  R*4   FRTEMP          2-0000002C  I*4   IBC             2-00000028  I*4   IBH
  3-000006FC  I*4   IBYT            2-00000034  I*4   ICH             3-00000700  I*4   IFLAG           2-00000030  I*4   IP
  4-000001F0  I*4   ISPAR1          4-00000008  I*4   ITIME           4-0000000C  I*4   ITIMSC          3-000006F8  I*4   KBT
  4-00000000  R*8   REV             4-00000030  R*4   RFTEMP          4-00000010  R*4   XLATSC          4-00000014  R*4   XLONSC

ARRAYS

    Address   Type  Name                Bytes  Dim  'ons

  4-000001F4  R*4   ALAT                  512  (128)
  4-000003F4  R*4   ALON                  512  (128)
  4-000005F4  R*4   BLAT                  512  (128)
  4-000007F4  R*4   BLON                  512  (128)
  4-0000006C  R*4   CALOFF                 28  (7)
  4-00000050  R*4   CALSLP                 28  (7)
  4-0000001C  R*4   HLTEMP                 12  (3)
  4-00000038  I*4   IAGC                   24  (6)
  4-00000088  I*4   ICOLDA                140  (5, 7)
  4-000001A0  I*4   ICOLDB                 40  (5, 2)
  4-00000114  I*4   IHOTA                 140  (5, 7)
  4-000001C8  I*4   IHOTB                  40  (5, 2)
  4-00001AF4  I*4   ISPAR2                256  (64)
  4-000016F4  I*4   ITOIL                1024  (4, 64)
  4-00000028  I*4   IVOLT                   8  (2)
  3-00000000  CHAR  LREC                 1784  (1784)
  2-00000000  R*4   SCALE1                 40  (10)
  4-00000EF4  R*4   TAHI                 2048  (8, 64)
  4-000009F4  R*4   TALO                 1280  (5, 64)
```

LABELS

Address	Label	Address	Label	Address	Label	Address	Label	Address	Label	Address	Label
0-00000109	100	0-000001A7	200	0-00000235	300	0-000002C9	400	0-0000031C	500	0-000003AA	600

FUNCTIONS AND SUBROUTINES REFERENCED

Type	Name	Type	Name
I*4	INT24	I*4	INT44

```
      C****************************************
```

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ FDCAL

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]FDCAL.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:           1.33 seconds
  Elapsed Time:       1.92 seconds
  Page Faults:        590
  Dynamic Memory:     440 pages
```

```
      SUBROUTINE FDLTLN(ISCAN)

C*********************************************************************
C     ISCAN = 1 ==> *ODD # PIXEL* LAT/LON FROM "A" SCAN ARE DECODED  *
C     ISCAN = 2 ==> ALL LAT/LON FROM "A" AND "B" SCAN ARE DECODED    *
C*********************************************************************

      INTEGER*4 INDEX(19),JNDEX(3,109),IBLT,IBLN,IBZD,ISCAN

C********************************
C     SPECIFY COMMON /INDATA/  *
C********************************

      CHARACTER*1 LREC(1784)
      INTEGER*4 KBT,IBYT,IFLAG
      COMMON/INDATA/LREC,KBT,IBYT,IFLAG

C********************************
C     SPECIFY COMMON /OUTDAT/  *
C********************************

      REAL*8 REV
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB,ISPAR1
      INTEGER*4 ITOIL,ISPAR2
      REAL*4 XLATSC,XLONSC,ALTSC,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI

      COMMON/OUTDAT/ REV,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),ISPAR1,
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),TAHI(8,64),ITOIL(4,64),ISPAR2(64)

C****************************
C     DATA INITIALIZATION  *
C****************************

      DATA RAD/0.017453293/
      DATA INDEX/1,9,17,25,33,41,49,57,65,73,81,89,97,105,113,121,123,
     1 127,128/
      DATA JNDEX/
     1   5,  1,  9, 13,  9, 17, 21, 17, 25, 29, 25, 33, 37, 33, 41,
     1  45, 41, 49, 53, 49, 57, 61, 57, 65, 69, 65, 73, 77, 73, 81,
     1  85, 81, 89, 93, 89, 97,101, 97,105,109,105,113,117,113,121,
     1   3,  1,  5,  7,  5,  9, 11,  9, 13, 15, 13, 17, 19, 17, 21,
     1  23, 21, 25, 27, 25, 29, 31, 29, 33, 35, 33, 37, 39, 37, 41,
     1  43, 41, 45, 47, 45, 49, 51, 49, 53, 55, 53, 57, 59, 57, 61,
     1  63, 61, 65, 67, 65, 69, 71, 69, 73, 75, 73, 77, 79, 77, 81,
     1  83, 81, 85, 87, 85, 89, 91, 89, 93, 95, 93, 97, 99, 97,101,
     1 103,101,105,107,105,109,111,109,113,115,113,117,119,117,121,
     1 125,123,127,  2,  1,  3,  4,  3,  5,  6,  5,  7,  8,  7,  9,
     1  10,  9, 11, 12, 11, 13, 14, 13, 15, 16, 15, 17, 18, 17, 19,
     1  20, 19, 21, 22, 21, 23, 24, 23, 25, 26, 25, 27, 28, 27, 29,
     1  30, 29, 31, 32, 31, 33, 34, 33, 35, 36, 35, 37, 38, 37, 39,
     1  40, 39, 41, 42, 41, 43, 44, 43, 45, 46, 45, 47, 48, 47, 49,
     1  50, 49, 51, 52, 51, 53, 54, 53, 55, 56, 55, 57, 58, 57, 59,
     1  60, 59, 61, 62, 61, 63, 64, 63, 65, 66, 65, 67, 68, 67, 69,
```

```
     1  70, 69, 71, 72, 71, 73, 74, 73, 75, 76, 75, 77, 78, 77, 79,
     1  80, 79, 81, 82, 81, 83, 84, 83, 85, 86, 85, 87, 88, 87, 89,
     1  90, 89, 91, 92, 91, 93, 94, 93, 95, 96, 95, 97, 98, 97, 99,
     1 100, 99,101,102,101,103,104,103,105,106,105,107,108,107,109,
     1 110,109,111,112,111,113,114,113,115,116,115,117,118,117,119,
     1 120,119,121,122,121,123,124,123,125,126,125,127/


C***************************************
C     BEGIN EXECUTION                  *
C                                      *
C     SET TABLE LAT/LON FOR A-SCAN     *
C***************************************

      IBYT=263
      IBLT=IBYT
      IBLN=IBYT+38

      DO 100 JCEL=1,19
         ICEL=INDEX(JCEL)
C*******************************************************
C  NOTE THAT ALAT CHARS ARE READ AS SIGNED 2-BYTE INTEGER *
C*******************************************************

         ALAT(ICEL)=0.01*(INT24S(KBT,LREC(IBLT),LREC(IBLT+1))-9000)
         ALON(ICEL)=0.01*INT24(KBT,LREC(IBLN),LREC(IBLN+1))
         IF(ALON(ICEL).LT.0.) ALON(ICEL)=ALON(ICEL)+360.
         IF(ALON(ICEL).GE.360.) ALON(ICEL)=ALON(ICEL)-360.
         IBLT=IBLT+2
         IBLN=IBLN+2
  100 CONTINUE

C********************************
C     SET MID-POINTS FOR A-SCAN  *
C********************************

      NCEL=46
      IF(ISCAN.EQ.2) NCEL=109
      DO 200 JCEL=1,NCEL
         ICEL=JNDEX(1,JCEL)
         I1=JNDEX(2,JCEL)
         I2=JNDEX(3,JCEL)
         DIFLAT=ALAT(I2)-ALAT(I1)
         AVGLAT=0.5*(ALAT(I1)+ALAT(I2))
         DIFLON=ALON(I2)-ALON(I1)
         IF(DIFLON.GT.180.) DIFLON=DIFLON-360.
         IF(DIFLON.LT.-180.) DIFLON=DIFLON+360.
         AVGLON=ALON(I1)+0.5*DIFLON
         XSQ=(2.*RAD*AVGLAT)**2
         XFAC=1.-.16627142*XSQ+.00807934*XSQ*XSQ-.000151880*XSQ*XSQ*XSQ
         ALAT(ICEL)=AVGLAT*(1.+0.125*(RAD*DIFLON)**2*XFAC)
         X=RAD*(90.-ABS(AVGLAT))
         TANLAT=1./(X+X*X*X/3.)
         IF(AVGLAT.LT.0.) TANLAT=-TANLAT
         ALON(ICEL)=AVGLON-0.2500*RAD*DIFLAT*DIFLON*TANLAT
         IF(ALON(ICEL).LT.0.) ALON(ICEL)=ALON(ICEL)+360.
         IF(ALON(ICEL).GE.360.) ALON(ICEL)=ALON(ICEL)-360.
```

```
  200 CONTINUE

      IF(ISCAN.NE.2) RETURN

C*************************************
C     SET TABLE LAT/LON FOR B-SCAN   *
C*************************************

      IBLT=IBYT
      IBLN=IBYT+38
      IBZD=IBYT+76

C*****************************************************************
C  NOTE THAT IDEL AND BLAT CHARS ARE READ AS SIGNED 2-BYTE INTEGERS  *
C*****************************************************************

      DO 300 JCEL=1,19
         ICEL=INDEX(JCEL)
         IDEL=INT24S(KBT,LREC(IBZD),LREC(IBZD+1))
         LATDEL=(IDEL+30000)/1000-30
         LONDEL=IDEL+29100-1000*(LATDEL+30)
         BLAT(ICEL)=.01*(INT24S(KBT,LREC(IBLT),LREC(IBLT+1))
     1   +LATDEL-9000)
         BLON(ICEL)=.01*(INT24(KBT,LREC(IBLN),LREC(IBLN+1))+LONDEL)
         IF(BLON(ICEL).LT.0.) BLON(ICEL)=BLON(ICEL)+360.
         IF(BLON(ICEL).GE.360.) BLON(ICEL)=BLON(ICEL)-360.
         IBLT=IBLT+2
         IBLN=IBLN+2
         IBZD=IBZD+2
  300 CONTINUE

      IBYT=IBZD

C**********************************
C     SET MID-POINTS FOR B-SCAN   *
C**********************************

      DO 400 JCEL=1,109
         ICEL=JNDEX(1,JCEL)
         I1=JNDEX(2,JCEL)
         I2=JNDEX(3,JCEL)
         DIFLAT=BLAT(I2)-BLAT(I1)
         AVGLAT=0.5*(BLAT(I1)+BLAT(I2))
         DIFLON=BLON(I2)-BLON(I1)
         IF(DIFLON.GT.180.) DIFLON=DIFLON-360.
         IF(DIFLON.LT.-180.) DIFLON=DIFLON+360.
         AVGLON=BLON(I1)+0.5*DIFLON
         XSQ=(2.*RAD*AVGLAT)**2
         XFAC=1.-.16627142*XSQ+.00807934*XSQ*XSQ-.000151880*XSQ*XSQ*XSQ
         BLAT(ICEL)=AVGLAT*(1.+0.125*(RAD*DIFLON)**2*XFAC)
         X=RAD*(90.-ABS(AVGLAT))
         TANLAT=1./(X+X*X*X/3.)
         IF(AVGLAT.LT.0.) TANLAT=-TANLAT
         BLON(ICEL)=AVGLON-0.2500*RAD*DIFLAT*DIFLON*TANLAT
         IF(BLON(ICEL).LT.0.) BLON(ICEL)=BLON(ICEL)+360.
         IF(BLON(ICEL).GE.360.) BLON(ICEL)=BLON(ICEL)-360.
  400 CONTINUE
```

```
0172            RETURN
0173            END


PROGRAM SECTIONS

    Name                                 Bytes   Attributes

  0 $CODE                                 1490   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                1628   PIC CON REL LCL NOSHR NOEXE  RD   WRT QUAD
  3 INDATA                                1796   PIC OVR REL GBL   SHR NOEXE  RD   WRT QUAD
  4 OUTDAT                                7156   PIC OVR REL GBL   SHR NOEXE  RD   WRT QUAD

    Total Space Allocated                12070

ENTRY POINTS

    Address   Type  Name

  0-00000000        FDLTLN

VARIABLES

    Address   Type  Name          Address   Type  Name          Address   Type  Name          Address   Type  Name

  4-00000018  R*4   ALTSC       2-00000594  R*4   AVGLAT      2-0000059C  R*4   AVGLON      2-00000590  R*4   DIFLAT
  2-00000598  R*4   DIFLON      4-00000034  R*4   FRTEMP      2-00000588  I*4   I1          2-0000058C  I*4   I2
  2-0000056C  I*4   IBLN        2-00000568  I*4   IBLT        3-000006FC  I*4   IBYT        2-00000570  I*4   IBZD
  2-0000057C  I*4   ICEL        2-000005B0  I*4   IDEL        3-00000700  I*4   IFLAG      AP-00000004@ I*4   ISCAN
  4-000001F0  I*4   ISPAR1      4-00000008  I*4   ITIME       4-0000000C  I*4   ITIMSC      2-00000578  I*4   JCEL
  3-000006F8  I*4   KBT         2-000005B4  I*4   LATDEL      2-000005B8  I*4   LONDEL      2-00000580  I*4   NCEL
  2-00000574  R*4   RAD         4-00000000  R*8   REV         4-00000030  R*4   RFTEMP      2-000005AC  R*4   TANLAT
  2-000005A8  R*4   X           2-000005A4  R*4   XFAC        4-00000010  R*4   XLATSC      4-00000014  R*4   XLONSC
  2-000005A0  R*4   XSQ

ARRAYS

    Address   Type  Name                Bytes  Dimensions

  4-000001F4  R*4   ALAT                  512  (128)
  4-000003F4  R*4   ALON                  512  (128)
  4-000005F4  R*4   BLAT                  512  (128)
  4-000007F4  R*4   BLON                  512  (128)
  4-0000006C  R*4   CALOFF                 28  (7)
  4-00000050  R*4   CALSLP                 28  (7)
  4-0000001C  R*4   HLTEMP                 12  (3)
  4-00000038  I*4   IAGC                   24  (6)
  4-00000088  I*4   ICOLDA                140  (5, 7)
  4-000001A0  I*4   ICOLDB                 40  (5, 2)
  4-00000114  I*4   IHOTA                 140  (5, 7)
  4-000001C8  I*4   IHOTB                  40  (5, 2)
  2-00000000  I*4   INDEX                  76  (19)
```

```
  4-00001AF4  I*4   ISPAR2              256  (64)
  4-000016F4  I*4   ITOIL              1024  (4, 64)
  4-00000028  I*4   IVOLT                 8  (2)
  2-0000004C  I*4   JNDEX              1308  (3, 109)
  3-00000000  CHAR  LREC               1784  (1784)
  4-00000EF4  R*4   TAHI               2048  (8, 64)
  4-000009F4  R*4   TALO               1280  (5, 64)


LABELS

    Address    Label       Address    Label       Address    Label       Address    Label

  0-000000EA   100      0-000002B4   200      0-00000410   300      0-000005C6   400


FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name             Type  Name

   I*4  INT24             I*4  INT24S
```

```
C**********************************
```

COMMAND QUALIFIERS

```
  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ FDLTLN

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]FDLTLN.LIS;1
  /NOOBJECT
```

COMPILATION STATISTICS

```
  Run Time:          2.01 seconds
  Elapsed Time:      2.72 seconds
  Page Faults:       638
  Dynamic Memory:    476 pages
```

```
      SUBROUTINE FDTA(ISCAN)

C************************************************************************
C  ISCAN=1 ==> DOES TA'S FOR A-SCAN, ODD-NUMBERED PIXELS ONLY.           *
C              CHANNELS FOR THESE PIXELS ARE 19, 22, 37, AND 85GHZ        *
C  ISCAN=2 ==> DOES ALL OF ISCAN=1 PLUS 85GHZ TA'S FOR ALL OTHER A-SCAN  *
C              AND B-SCAN PIXELS                                          *
C************************************************************************

      INTEGER*4 IWORK4,IBL,IBH,ISCAN

C********************************
C     SPECIFY COMMON /INDATA/    *
C********************************

      CHARACTER*1 LREC(1784)
      INTEGER*4 KBT,IBYT,IFLAG
      COMMON/INDATA/LREC,KBT,IBYT,IFLAG

C********************************
C     SPECIFY COMMON /OUTDAT/    *
C********************************

      REAL*8 REV
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB,ISPAR1
      INTEGER*4 ITOIL,ISPAR2
      REAL*4 XLATSC,XLONSC,ALTSC,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI

      COMMON/OUTDAT/ REV,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),ISPAR1,
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),TAHI(8,64),ITOIL(4,64),ISPAR2(64)

C**********************
C     BEGIN EXECUTION  *
C**********************

      IBYT = 377
      IBL = IBYT
      IBH = IBYT+640

      DO 100 ICEL=1,64

C************************************************
C     FIND THE TA'S FOR THE 3 LOWER FREQUENCIES  *
C************************************************

         DO 50 ICH=1,5,2
            IWORK4=INT34(KBT,LREC(IBL),LREC(IBL+1),LREC(IBL+2))
            IBL = IBL+3
            ITAV=INT(IWORK4/4096)
            TALO(ICH,ICEL)=0.1*ITAV
            IF(ITAV.GT.3800) TALO(ICH,ICEL)=ITAV-3420
            ITAH=IWORK4-4096*ITAV
            IF(ICH.EQ.5) GO TO 60
```

```
               TALO(ICH+1,ICEL)=0.1*ITAH
               IF(ITAH.GT.3800) TALO(ICH+1,ICEL)=ITAH-3420
   50       CONTINUE
   50       CONTINUE

            ISPAR2(ICEL)=INT14(KBT,LREC(IBL))
            IBL = IBL+1

C***************************
C     FIND THE TOIL FLAGS  *
C***************************

            ITOIL1=INT(ITAH/512)
            IRES=ITAH-ITOIL1*512
            ITOIL2=IRES/64
            IRES=IRES-ITOIL2*64
            ITOIL3=IRES/8
            ITOIL4=IRES-ITOIL3*8
            ITOIL(1,ICEL)=ITOIL1
            ITOIL(2,ICEL)=ITOIL2
            ITOIL(3,ICEL)=ITOIL3
            ITOIL(4,ICEL)=ITOIL4

C**********************************************************
C     FIND 85 GHZ TA'S FOR ODD # PIXELS IN THE A-SCAN    *
C**********************************************************

            ICH = 1
            IWORK4=INT34(KBT,LREC(IBH),LREC(IBH+1),LREC(IBH+2))
            IBH = IBH+12
            ITAV=INT(IWORK4/4096)
            TAHI(ICH,ICEL)=0.1*ITAV
            IF(ITAV.GT.3800) TAHI(ICH,ICEL)=ITAV-3420
            ITAH=IWORK4-4096*ITAV
            TAHI(ICH+1,ICEL)=0.1*ITAH
            IF(ITAH.GT.3800) TAHI(ICH+1,ICEL)=ITAH-3420
  100 CONTINUE

        IF(ISCAN .NE. 2)RETURN

        IBH=IBYT+640

C*********************************************
C  FIND THE 85GHZ TA'S FOR ALL OTHER PIXELS  *
C*********************************************

        DO 200 ICEL=1,64
           IBH=IBH+3
           DO 150 ICH=3,7,2
              IWORK4=INT34(KBT,LREC(IBH),LREC(IBH+1),LREC(IBH+2))
              IBH = IBH+3
              ITAV=INT(IWORK4/4096)
              TAHI(ICH,ICEL)=0.1*ITAV
              IF(ITAV.GT.3800) TAHI(ICH,ICEL)=ITAV-3420
              ITAH=IWORK4-4096*ITAV
              TAHI(ICH+1,ICEL)=0.1*ITAH
              IF(ITAH.GT.3800) TAHI(ICH+1,ICEL)=ITAH-3420
```

```
0115      150    CONTINUE
0116      200 CONTINUE
0117          RETURN
0118          END
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	872	PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL	200	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
3 INDATA	1796	PIC OVR REL GBL SHR NOEXE RD WRT QUAD
4 OUTDAT	7156	PIC OVR REL GBL SHR NOEXE RD WRT QUAD
Total Space Allocated	10024	

ENTRY POINTS

Address	Type	Name
0-00000000		FDTA

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name	Address	Type	Name
4-00000018	R*4	ALTSC	4-00000034	R*4	FRTEMP	2-00000008	I*4	IBH	2-00000004	I*4	IBL
3-000006FC	I*4	IBYT	2-0000000C	I*4	ICEL	2-00000010	I*4	ICH	3-00000700	I*4	IFLAG
2-00000020	I*4	IRES	AP-00000004@	I*4	ISCAN	4-000001F0	I*4	ISPAR1	2-00000018	I*4	ITAH
2-00000014	I*4	ITAV	4-00000008	I*4	ITIME	4-0000000C	I*4	ITIMSC	2-0000001C	I*4	ITOIL1
2-00000024	I*4	ITOIL2	2-00000028	I*4	ITOIL3	2-0000002C	I*4	ITOIL4	2-00000000	I*4	IWORK4
3-000006F8	I*4	KBT	4-00000000	R*8	REV	4-00000030	R*4	RFTEMP	4-00000010	R*4	XLATSC
4-00000014	R*4	XLONSC									

ARRAYS

Address	Type	Name	Bytes	Dimensions
4-000001F4	R*4	ALAT	512	(128)
4-000003F4	R*4	ALON	512	(128)
4-000005F4	R*4	BLAT	512	(128)
4-000007F4	R*4	BLON	512	(128)
4-0000006C	R*4	CALOFF	28	(7)
4-00000050	R*4	CALSLP	28	(7)
4-0000001C	R*4	HLTEMP	12	(3)
4-00000038	I*4	IAGC	24	(6)
4-00000088	I*4	ICOLDA	140	(5, 7)
4-000001A0	I*4	ICOLDB	40	(5, 2)
4-00000114	I*4	IHOTA	140	(5, 7)
4-000001C8	I*4	IHOTB	40	(5, 2)
4-00001AF4	I*4	ISPAR2	256	(64)

```
  4-000016F4  I*4  ITOIL              1024  (4, 64)
  4-00000028  I*4  IVOLT                 8  (2)
  3-00000000  CHAR LREC               1784  (1784)
  4-00000EF4  R*4  TAHI               2048  (8, 64)
  4-000009F4  R*4  TALO               1280  (5, 64)
```

LABELS

Address	Label	Address	Label	Address	Label	Address	Label	Address	Label
0-000000FA	50	0-00000101	60	0-00000261	100	0-00000355	150	0-0000035C	200

FUNCTIONS AND SUBROUTINES REFERENCED

Type	Name	Type	Name
I*4	INT14	I*4	INT34

```
C*******************************
```

COMMAND QUALIFIERS

```
  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ FDTA

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]FDTA.LIS;1
  /NOOBJECT
```

COMPILATION STATISTICS

```
  Run Time:          1.20 seconds
  Elapsed Time:      1.87 seconds
  Page Faults:       555
  Dynamic Memory:    396 pages
```

```
      subroutine geobox (lat, lon, dplc, box)

c*****************************************************************
c   Subroutine GEOBOX defines the 'corners' of a box on the earth's *
c   surface given its center, and an arbitrary surface displacement *
c   from said center.  The boundary values of this box are stored in *
c   an array for later use.                                          *
c*****************************************************************

      real lat, lon, dplc, box(4), rad2deg
      real e_rad, dplc_angle

c*****************************************
c   Earth Radius (polar orbit; kilometers) *
c*****************************************
      e_rad = 6356.913

c***************************************************************
c   Compute (infer) the 'corners' of a box with the given lat/lon  *
c   coordinates as its center.  Return the min/max latitude and    *
c   longitudes in the 4-element 1-D array "box()", the contents of *
c   which are:    box(1) = minimum latitude                        *
c                 box(2) = maximum latitude                        *
c                 box(3) = minimum longitude                       *
c                 box(4) = maximum longitude                       *
c***************************************************************
      rad2deg = 180.0 / 3.14159265
      dplc_angle = asin(dplc/e_rad) * rad2deg
      box(1) = lat - dplc_angle
      box(2) = lat + dplc_angle
      box(3) = lon - dplc_angle
      box(4) = lon + dplc_angle

      return
      end
```

```
PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                    97   PIC CON REL LCL   SHR   EXE    RD NOWRT QUAD
  2 $LOCAL                                   44   PIC CON REL LCL NOSHR NOEXE    RD   WRT QUAD

    Total Space Allocated                   141

ENTRY POINTS

    Address   Type  Name

  0-00000000        GEOBOX

VARIABLES

    Address   Type  Name                Address   Type  Name                Address   Type  Name                Address   Type  Name

 AP-0000000C@ R*4   DPLC              2-00000008  R*4   DPLC_ANGLE        2-00000004  R*4   E_RAD             AP-00000004@ R*4   LAT
 AP-00000008@ R*4   LON               2-00000000  R*4   RAD2DEG

ARRAYS

    Address   Type  Name                  Bytes  Dimensions

 AP-00000010@ R*4   BOX                    · 16  (4)

FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name

   R*4  MTH$ASIN

COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ GEOBOX

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]GEOBOX.LIS;1
  /NOOBJECT
```

```
COMPILATION STATISTICS

  Run Time:           0.34 seconds
  Elapsed Time:       0.83 seconds
  Page Faults:        448
  Dynamic Memory:     332 pages
```

```
      SUBROUTINE GTLAT(GTL)

C**************************************************************
C  CALCULATES LATITUDE OF GROUND TRACK POINT FROM REGRESSION  *
C  ON SCAN PIXELS 3,63 AND 125 (IE. 2,32,63 IN 64 PIX SCAN)   *
C**************************************************************

      REAL CF(4)

C*******************************
C     SPECIFY COMMON /OUTDAT/  *
C*******************************

      REAL*8 REV
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB,ISPAR1
      INTEGER*4 ITOIL,ISPAR2
      REAL*4 XLATSC,XLONSC,ALTSC,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI

      COMMON/OUTDAT/ REV,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),ISPAR1,
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),TAHI(8,64),ITOIL(4,64),ISPAR2(64)

      DATA CF/-0.129,1.533,-1.928,1.411/

      GTL = CF(1)+CF(2)*ALAT(3)+CF(3)*ALAT(63)+CF(4)*ALAT(125)
      RETURN
      END
```

```
PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                    49   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                   16   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD
  3 OUTDAT                                 7156   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD

    Total Space Allocated                  7221


ENTRY POINTS

    Address   Type  Name

  0-00000000        GTLAT


VARIABLES

    Address   Type  Name            Address   Type  Name            Address   Type  Name          Address   Type  Name

  3-00000018  R*4   ALTSC         3-00000024  R*4   FRTEMP       AP-00000004@ R*4   GTL         3-000001F0  I*4   ISPAR1
  3-00000008  I*4   ITIME         3-0000000C  I*4   ITIMSC         3-00000000 R*8   REV         3-00000030  R*4   RFTEMP
  3-00000010  R*4   XLATSC        3-00000014  R*4   XLONSC


ARRAYS

    Address   Type  Name              Bytes  Dimensions

  3-000001F4  R*4   ALAT                512  (128)
  3-000003F4  R*4   ALON                512  (128)
  3-000005F4  R*4   BLAT                512  (128)
  3-000007F4  R*4   BLON                512  (128)
  3-0000006C  R*4   CALOFF               28  (7)
  3-00000050  R*4   CALSLP               28  (7)
  2-00000000  R*4   CF                   16  (4)
  3-0000001C  R*4   HLTEMP               12  (3)
  3-00000038  I*4   IAGC                 24  (6)
  3-00000088  I*4   ICOLDA              140  (5, 7)
  3-000001A0  I*4   ICOLDB               40  (5, 2)
  3-00000114  I*4   IHOTA               140  (5, 7)
  3-000001C8  I*4   IHOTB                40  (5, 2)
  3-00001AF4  I*4   ISPAR2              256  (64)
  3-000016F4  I*4   ITOIL              1024  (4, 64)
  3-00000028  I*4   IVOLT                 8  (2)
  3-00000EF4  R*4   TAHI               2048  (8, 64)
  3-000009F4  R*4   TALO               1280  (5, 64)
```

```
C***********************************
```

COMMAND QUALIFIERS

```
  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ GTLAT

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]GTLAT.LIS;1
  /NOOBJECT
```

COMPILATION STATISTICS

```
  Run Time:          0.39 seconds
  Elapsed Time:      0.83 seconds
  Page Faults:       425
  Dynamic Memory:    200 pages
```

```
      FUNCTION INT24(KBT,BYT1,BYT2)

C**********************************************************************
C  THIS ROUTINE CONVERTS A 2-BYTE ARRAY INTO A 4-BYTE POSITIVE INTEGER  *
C  *** USE FUNCTION INT24S IF DECODING A 2-BYTE SIGNED INTEGER ***      *
C  KBT=1 ==> VAX,      KBT=2 ==> IBM OR HP                               *
C**********************************************************************

      INTEGER*4 NUM,KBT
      INTEGER*2 ISWP(2,2)
      CHARACTER*1 BAR(4),BYT1,BYT2
      EQUIVALENCE (BAR(1),NUM)
      DATA ISWP/2,1,3,4/
      NUM = 0
      BAR(ISWP(1,KBT)) = BYT1
      BAR(ISWP(2,KBT)) = BYT2
      INT24 = NUM
      RETURN
      END
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	70	PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL	32	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
Total Space Allocated	102	

ENTRY POINTS

Address	Type	Name
0-00000000	I*4	INT24

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name	Address	Type	Name
AP-00000008@	CHAR	BYT1	AP-0000000C@	CHAR	BYT2	AP-00000004@	I*4	KBT	2-00000000	I*4	NUM

ARRAYS

Address	Type	Name	Bytes	Dimensions
2-00000000	CHAR	BAR	4	(4)
2-00000004	I*2	ISWP	8	(2, 2)

```
C********************************


      FUNCTION INT24S(KBT,BYT1,BYT2)

C*************************************************************************
C  THIS ROUTINE CONVERTS A 2-BYTE ARRAY INTO A 4-BYTE INTEGER            *
C  KBT=1 ==> VAX,      KBT=2 ==> IBM OR HP                               *
C  *** THIS PROGRAM WILL WORK IF THE 2-BYTE ARRAY IS INTENDED TO     *** *
C  *** REPRESENT A SIGNED 2-BYTE INTEGER.                            *** *
C  *** NOTE THAT WE CANNOT DIRECTLY PUT THE BYTES INTO A 4-BYTE INTEGER *** *
C  *** BUFFER OTHERWISE WE WILL NOT RECOVER THE SIGN BIT.            *** *
C*************************************************************************

      INTEGER*4 KBT
      INTEGER*2 ISWP(2,2),NUM
      CHARACTER*1 BAR(2),BYT1,BYT2
      EQUIVALENCE (BAR(1),NUM)
      DATA ISWP/2,1,1,2/
      BAR(ISWP(1,KBT)) = BYT1
      BAR(ISWP(2,KBT)) = BYT2
      INT24S = NUM
      RETURN
      END
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	67	PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL	32	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
Total Space Allocated	99	

ENTRY POINTS

Address	Type	Name
0-00000000	I*4	INT24S

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name	Address	Type	Name
AP-00000008@	CHAR	BYT1	AP-0000000C@	CHAR	BYT2	AP-00000004@	I*4	KBT	2-00000000	I*2	NUM

ARRAYS

Address	Type	Name	Bytes	Dimensions
2-00000000	CHAR	BAR	2	(2)
2-00000002	I*2	ISWP	8	(2, 2)

```
C*******************************************


      FUNCTION INT44(KBT,BYT1,BYT2,BYT3,BYT4)

C*****************************************************************
C  THIS ROUTINE CONVERTS A 4-BYTE ARRAY INTO A 4-BYTE INTEGER     *
C  KBT=1 ==> VAX,        KBT=2 ==> IBM OR HP                      *
C  *** THIS PROGRAM WILL WORK IF THE 4-BYTE ARRAY IS INTENDED ***  *
C  *** TO REPRESENT A NEGATIVE INTEGER.(IE. SIGN BIT USED)    ***  *
C*****************************************************************

      INTEGER*4 NUM,KBT
      INTEGER*2 ISWP(4,2)
      CHARACTER*1 BAR(4),BYT1,BYT2,BYT3,BYT4
      EQUIVALENCE (BAR(1),NUM)
      DATA ISWP/4,3,2,1,1,2,3,4/
      NUM = 0
      BAR(ISWP(1,KBT)) = BYT1
      BAR(ISWP(2,KBT)) = BYT2
      BAR(ISWP(3,KBT)) = BYT3
      BAR(ISWP(4,KBT)) = BYT4
      INT44 = NUM
      RETURN
      END
```

```
PROGRAM SECTIONS

    Name                                       Bytes   Attributes

  0 $CODE                                        118   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                        56   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                        174

ENTRY POINTS

    Address   Type  Name

  0-00000000  I*4   INT44

VARIABLES

    Address   Type  Name          Address   Type  Name          Address   Type  Name          Address   Type  Name

 AP-00000008@ CHAR BYT1      AP-0000000C@ CHAR BYT2      AP-00000010@ CHAR BYT3      AP-00000014@ CHAR BYT4
 AP-00000004@ I*4  KBT        2-00000000  I*4  NUM
```

```
ARRAYS

    Address   Type  Name                Bytes  Dimensions

  2-00000000  CHAR  BAR                     4  (4)
  2-00000004  I*2   ISWP                   16  (4, 2)
```

```
C***************************************


      FUNCTION INT34(KBT,BYT1,BYT2,BYT3)

C***************************************************************************
C  THIS ROUTINE CONVERTS A 3-BYTE ARRAY INTO A 4-BYTE POSITIVE INTEGER    *
C  KBT=1 ==> VAX,      KBT=2 ==> IBM OR HP                                 *
C  *** THIS PROGRAM WILL PRODUCE ONLY POSITIVE INTEGER OUTPUTS ***        *
C***************************************************************************

      INTEGER*4 NUM,KBT
      INTEGER*2 ISWP(3,2)
      CHARACTER*1 BAR(4),BYT1,BYT2,BYT3
      EQUIVALENCE (BAR(1),NUM)
      DATA ISWP/3,2,1,2,3,4/
      NUM = 0
      BAR(ISWP(1,KBT)) = BYT1
      BAR(ISWP(2,KBT)) = BYT2
      BAR(ISWP(3,KBT)) = BYT3
      INT34 = NUM
      RETURN
      END
```

```
PROGRAM SECTIONS

    Name                              Bytes   Attributes

  0 $CODE                                94   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                               44   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated               138

ENTRY POINTS

    Address   Type  Name

  0-00000000  I*4   INT34

VARIABLES

    Address   Type  Name            Address   Type  Name            Address   Type  Name            Address   Type  Name

 AP-00000008@ CHAR BYT1        AP-0000000C@ CHAR BYT2        AP-00000010@ CHAR BYT3        AP-00000004@ I*4  KBT
  2-00000000  I*4  NUM
```

```
ARRAYS

    Address   Type  Name                 Bytes  Dimensions

  2-00000000  CHAR BAR                      4  (4)
  2-00000004  I*2  ISWP                    12  (3, 2)
```

```
C*********************************


      FUNCTION INT14(KBT,BYT1)

C*************************************************************************
C  THIS ROUTINE CONVERTS A 1-BYTE ARRAY INTO A 4-BYTE POSITIVE INTEGER  *
C  KBT=1 ==> VAX,       KBT=2 ==> IBM OR HP                              *
C  *** THIS PROGRAM WILL PRODUCE ONLY POSITIVE INTEGER OUTPUTS ***       *
C*************************************************************************

      INTEGER*4 NUM,KBT
      INTEGER*2 ISWP(2)
      CHARACTER*1 BAR(4),BYT1
      EQUIVALENCE (BAR(1),NUM)
      DATA ISWP/1,4/
      NUM = 0
      BAR(ISWP(KBT)) = BYT1
      INT14 = NUM
      RETURN
      END
```

```
PROGRAM SECTIONS

    Name                                Bytes   Attributes

  0 $CODE                                  45   PIC CON REL LCL   SHR   EXE    RD NOWRT QUAD
  2 $LOCAL                                 20   PIC CON REL LCL NOSHR NOEXE    RD   WRT QUAD

    Total Space Allocated                  65


ENTRY POINTS

    Address   Type  Name

  0-00000000  I*4   INT14


VARIABLES

    Address   Type  Name              Address   Type  Name              Address   Type  Name

 AP-00000008@ CHAR BYT1          AP-00000004@ I*4   KBT             2-00000000   I*4   NUM


ARRAYS

    Address   Type  Name                          Bytes  Dimensions

  2-00000000  CHAR  BAR                              4   (4)
  2-00000004  I*2   ISWP                             4   (2)
```

```
0001      C*********************************
0002
0003
```

COMMAND QUALIFIERS

```
  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ INTFUNC

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]INTFUNC.LIS;1
  /NOOBJECT
```

COMPILATION STATISTICS

```
  Run Time:           0.92 seconds
  Elapsed Time:       1.66 seconds
  Page Faults:        443
  Dynamic Memory:     328 pages
```

```
      subroutine openreg ()
C*********************************************************************
C   Subroutine OPENREG simply opens the output files necessary to keep  *
C   track of the regional microwave data processed from the SSM/I data  *
C   tape in question.                                                   *
C*********************************************************************

      open (11, status='unknown', file='Lenigrad.dat')
      open (12, status='unknown', file='Kiev.dat')
      open (13, status='unknown', file='Simferopol.dat')
      open (14, status='unknown', file='Moscow.dat')
      open (15, status='unknown', file='Murmansk.dat')
      open (16, status='unknown', file='Perm.dat')
      open (17, status='unknown', file='Aktyubinsk.dat')
      open (18, status='unknown', file='Tashkent.dat')
      open (19, status='unknown', file='Semipalatinsk.dat')
      open (20, status='unknown', file='Chita.dat')
      open (21, status='unknown', file='Blagoveschensk.dat')

      return
      end
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	105	PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $PDATA	145	PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL	352	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
Total Space Allocated	602	

ENTRY POINTS

Address	Type	Name
0-00000000		OPENREG

FUNCTIONS AND SUBROUTINES REFERENCED

Type	Name
	FOR$OPEN

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ OPENREG

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]OPENREG.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:           0.37 seconds
  Elapsed Time:       0.86 seconds
  Page Faults:        372
  Dynamic Memory:     200 pages
```

```
      SUBROUTINE QTIME(ITREF,ITNOW,ITIME,IERR,IFUNCT)

C**********************************************************************
C  SUBROUTINE CREATED: 11 JULY 1988                                   *
C  USE THIS SUBROUTINE TO CONVERT A (YEAR,MONTH,DAY.HR,MIN,SEC)"NOW"  *
C  TIME GROUP INTO A TIME, ITIME,(IN SECONDS) WHICH IS COUNTED FROM THE *
C  (YEAR,MONTH,DAY,HR,MIN,SEC)"REF" TIME GROUP  **OR** GIVEN A "REF"  *
C  TIME GROUP AND "ITIME", THE PROGRAM WILL CALCULATE THE "NOW" TIME GROUP.*
C  PROGRAM WILL HANDLE ANY TIME GROUP FROM THE YEARS 1940 THRU 1999.  *
C  VARIABLE DESCRIPTIONS:                                             *
C     IFUNCT    -  VARIABLE INDICATING WHAT IS TO BE CALCULATED       *
C                    1 ==>GIVEN ITREF AND ITNOW CALCULATE ITIME        *
C                    2 ==>GIVEN ITREF AND ITIME CALCULATE ITNOW        *
C     ITREF(.)  -  7 ELEMENT ARRAY CONTAINING REFERENCE TIME GROUP    *
C                  ITREF(1) = YEAR,    RANGE = (40,99)                 *
C                  ITREF(2) = MONTH,   RANGE = (1,12)                  *
C                  ITREF(3) = DAY,     RANGE = (1,31)                  *
C                  ITREF(4) = HOUR,    RANGE = (0,23)                  *
C                  ITREF(5) = MINUTE,  RANGE = (0,59)                  *
C                  ITREF(6) = SECOND,  RANGE = (0,59)                  *
C                  ITREF(7) = LEAP YEAR INDICATOR, 1=NORMAL YR, 2=LEAP YR *
C     ITNOW(.)  -  7 ELEMENT ARRAY CONTAINING " NOW " TIME GROUP      *
C     ITIME     -  DIFFERENCE IN SECONDS BETWEEN REF TIME AND NOW TIME *
C     IERR      -  ERROR FLAG                                         *
C                    0 ==> NO ERRORS                                  *
C                    I ==> ITNOW(I) OR ITREF(I) IS OUT OF RANGE       *
C     LY(.)     -  ARRAY INDICATING WHICH YEARS ARE LEAP YEARS        *
C                    1 ==> NORMAL YEAR                                *
C                    2 ==> LEAP YEAR                                  *
C     JULIAN(I,J)- ARRAY CONTAINING THE JULIAN DAY CORRESPONDING TO   *
C                  THE START OF EACH MONTH "I".                       *
C                    J=1 ==> NORMAL YEAR                              *
C                    J=2 ==> LEAP YEAR                                *
C     IYEAR(.)  -  ARRAY CONTAINING NUMBER OF SECONDS IN NORMAL YEAR  *
C                  AND IN A LEAP-YEAR                                 *
C                                                                     *
C**********************************************************************

       INTEGER ITREF(7),ITNOW(7),JULIAN(12,2),IYEAR(2),LY(60)
       INTEGER IRANGE(6,2)
       DATA IYEAR/31536000,31622400/
       DATA JULIAN/1,32,60,91,121,152,182,213,244,274,305,335,
     &            1,32,61,92,122,153,183,214,245,275,306,336/
       DATA IRANGE/40, 1, 1, 0, 0, 0,
     &            99,12,31,23,59,59/
       IERR=0
       DO 5 I=1,6
        IF(ITREF(I).LT.IRANGE(I,1).OR.ITREF(I).GT.IRANGE(I,2))IERR=I
        IF(IFUNCT.EQ.2)GO TO 5
        IF(ITNOW(I).LT.IRANGE(I,1).OR.ITNOW(I).GT.IRANGE(I,2))IERR=I
    5  CONTINUE
       IF(IERR.NE.0)RETURN
C  FILL LEAP-YEAR INDICATOR ARRAY
       I1=1
       DO 10 I=1,15
        LY(I1)=2
        I1=I1+1
```

```
          LY(I1)=1
          I1=I1+1
          LY(I1)=1
          I1=I1+1
          LY(I1)=1
          I1=I1+1
   10 CONTINUE
C  CALCULATE "REF" TIME IN SECONDS FROM BEGINNING OF REF YEAR
         IY1=ITREF(1)-39
         IL1=LY(IY1)
         ISTART=(JULIAN(ITREF(2),IL1)+ITREF(3)-2)*86400
         ISTART=ISTART+ITREF(4)*3600+ITREF(5)*60+ITREF(6)
         IF(IFUNCT.EQ.2)GO TO 100
C
C  ** IFUNCT=1  MODULE FOLLOWS
C
C  CALCULATE "NOW" TIME IN SECONDS FROM BEGINNING OF "NOW" YEAR
         IY2=ITNOW(1)-39
         IL2=LY(IY2)
         ITNOW(7)=IL2
         IEND=(JULIAN(ITNOW(2),IL2)+ITNOW(3)-2)*86400
         IEND=IEND+ITNOW(4)*3600+ITNOW(5)*60+ITNOW(6)
         ITIME=IEND-ISTART
         IERR=0
         I2=IY2-1
         DO 20 I=IY1,I2
          IL=LY(I)
          ITIME=ITIME+IYEAR(IL)
   20    CONTINUE
         RETURN
C
C  ** IFUNCT=2 MODULE FOLLOWS
C
  100    CONTINUE
         IY2=IY1
         ISUM=IYEAR(LY(IY2))-ISTART
  110    CONTINUE
          IF(ISUM.GT.ITIME)GO TO 120
          IY2=IY2+1
          ISUM=ISUM+IYEAR(LY(IY2))
         GO TO 110
  120    IEND=ITIME-ISUM+IYEAR(LY(IY2))
         IL2=LY(IY2)
         ITNOW(7)=IL2
         JDAY=IEND/86400+1
         IEND=IEND-(JDAY-1)*86400
         ITNOW(4)=IEND/3600
         IEND=IEND-ITNOW(4)*3600
         ITNOW(5)=IEND/60
         ITNOW(6)=IEND-ITNOW(5)*60
         IM=1
  130    CONTINUE
          IF(JDAY.LT.JULIAN(IM,IL2))GO TO 140
          IM=IM+1
         GO TO 130
  140    IM=IM-1
         ITNOW(2)=IM
```

```
              ITNOW(3)=JDAY-JULIAN(IM,IL2)+1
              ITNOW(1)=IY2+39
              RETURN
              END


PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                   719   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                  512   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                  1231

ENTRY POINTS

    Address   Type  Name

  0-00000000        QTIME

VARIABLES

    Address   Type  Name              Address   Type  Name              Address   Type  Name              Address   Type  Name

  2-00000188  I*4   I              2-0000018C  I*4   I1              2-000001A8  I*4   I2              2-000001A4  I*4   IEND
 AP-00000010@ I*4   IERR          AP-00000014@ I*4   IFUNCT          2-000001B0  I*4   IL              2-00000194  I*4   IL1
  2-000001A0  I*4   IL2            2-000001BC  I*4   IM              2-000001^8  I*4   ISTART          2-000001B4  I*4   ISUM
 AP-0000000C@ I*4   ITIME          2-00000190  I*4   IY1             2-0000019C  I*4   IY2             2-000001B8  I*4   JDAY

ARRAYS

    Address   Type  Name              Bytes  Dimensions

  2-00000158  I*4   IRANGE               48  (6, 2)
 AP-00000008@ I*4   ITNOW                28  (7)
 AP-00000004@ I*4   ITREF                28  (7)
  2-00000060  I*4   IYEAR                 8  (2)
  2-00000000  I*4   JULIAN               96  (12, 2)
  2-00000068  I*4   LY                  240  (60)

LABELS

    Address   Label      Address   Label      Address   Label      Address   Label      Address   Label      Address   Label

  0-0000006F  5       0-000000B4  10       0-000001C3  20       0-000001C8  100      0-000001E0  110      0-000001FD  120
  0-00000287  130     0-0000029E  140
```

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ QTIME

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]QTIME.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:            1.21 seconds
  Elapsed Time:        2.00 seconds
  Page Faults:         523
  Dynamic Memory:      392 pages
```

```
      SUBROUTINE SWATH(ISCAN,KFLAG)

C*****************************************************************
C  PROGRAM USED TO STRIP SWATH DATA FROM THE WENTZ SSMI TAPES    *
C  **THIS LATEST VERSION(19FEB88) ALLOWS USER TO STRIP MORE THAN** *
C  **ONE SWATH AT A TIME**                                        *
C   ISCAN=1 => OUTPUT A-SCAN, ODD-PIXEL, TB'S AND WSP             *
C   ISCAN=2 => OUTPUT ONLY 85GHZ TA DATA FOR ALL A&B SCAN PIXELS  *
C                                                                 *
C  Severe modifications made for AFGL/LYS by James S. Belfiore, Jr. *
C  (30-APR-1990) and AER, Inc.                                    *
C*****************************************************************

      INTEGER JULIAN(12,2),STIME(10),ETIME(10),RAINF(64)
      INTEGER ITREF(7),ITNOW(7)
      CHARACTER FNAME(10)*10, SC*1,DECIS*1
      REAL*4 WIND(64),TB(7,64)

      real regions(11,4)
      logical reg_flg

C******************************
C     SPECIFY COMMON /INDATA/    *
C******************************

      CHARACTER*1 LREC(1784)
      INTEGER*4 KBT,IBYT,IFLAG
      COMMON/INDATA/LREC,KBT,IBYT,IFLAG

C******************************
C     SPECIFY COMMON /OUTDAT/    *
C******************************

      REAL*8 REV
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB,ISPAR1
      INTEGER*4 ITOIL,ISPAR2
      REAL*4 XLATSC,XLONSC,ALTSC,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI

      COMMON/OUTDAT/ REV,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),ISPAR1,
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),TAHI(8,64),ITOIL(4,64),ISPAR2(64)

      DATA ITREF/87,1,1,0,0,0,1/
      DATA JULIAN/1,32,60,91,121,152,182,213,244,274,305,335,
     &            1,32,61,92,122,153,183,214,245,275,306,336/

      OPEN(1,STATUS='OLD',BLOCKSIZE=28544,RECL=1784,
     & RECORDTYPE='FIXED',FORM='FORMATTED')

C****************************
C  READ PAST THE TAPE HEADERS *
C****************************

      CALL READHD
```

```
      WRITE(6,1010)
 1010 FORMAT(/' THIS OPTION ALLOWS THE USER TO STRIP SWATH DATA FROM'/
     &         ' THE TAPE. MORE THAN ONE SWATH CAN BE EXTRACTED AT A'/
     &         ' TIME HOWEVER, THE SWATH TIMES MUST BE ENTERED IN'/
     &         ' **ASCENDING** ORDER.')

      IFILE=0
    1 IFILE=IFILE+1
      WRITE(6,1000)
 1000 FORMAT(//' FOR THE SWATH DATA TO BE EXTRACTED ENTER,'//
     &'     START DATE (YR MM DD)(e.g. 87 1 25): ',$)
      READ(5,*)ITNOW(1),ITNOW(2),ITNOW(3)
      WRITE(6,1100)
 1100 FORMAT('     START TIME (HH MM SS)(e.g. 0 0 0): ',$)
      READ(5,*)ITNOW(4),ITNOW(5),ITNOW(6)
      CALL QTIME(ITREF,ITNOW,ITIME,IERR,1)
      STIME(IFILE)=ITIME
      WRITE(6,1200)
 1200 FORMAT('     END DATE (YR MM DD): ',$)
      READ(5,*)ITNOW(1),ITNOW(2),ITNOW(3)
      WRITE(6,1300)
 1300 FORMAT('     END TIME (HH MM SS): ',$)
      READ(5,*)ITNOW(4),ITNOW(5),ITNOW(6)
      CALL QTIME(ITREF,ITNOW,ITIME,IERR,1)
      ETIME(IFILE)=ITIME
      WRITE(6,1400)
 1400 FORMAT('     OUTPUT FILE NAME: '$)
      READ(5,1500)FNAME(IFILE)
 1500 FORMAT(A20)
      WRITE(6,1550)
 1550 FORMAT(//' WOULD YOU LIKE TO EXTRACT OTHER SWATH DATA FROM',
     &' THIS TAPE? (Y/N): ',$)
      READ(5,1560)DECIS
 1560 FORMAT(A1)
      IF(DECIS.EQ.'Y'.OR.DECIS.EQ.'y')GO TO 1

      DUM=0.0
      IREC=0
      IREC2=0
      WRITE(6,1800)
 1800 FORMAT(///'      REC NO')

      DO 990 IF=1,IFILE
         call openreg ()
         open (2, status='new', name=fname(if))

C***********************************
C  WRITE HEADERS TO THE OUTPUT FILE  *
C***********************************

         IF(ISCAN .EQ. 1) WRITE(2,1600)
         IF(ISCAN .EQ. 2) WRITE(2,1700)

 1600    format ('   time     lat     lon      tb19v   tb19h',
     &   '   tb22v   tb37v   tb37h')
 1700    format ('   time     lat     lon     ta85v   ta85h')

```

```
C*****************************
C   Establish target regions  *
C*****************************
         call estreg (regions)

   10    IEOF=0
         reg_flg = .false.
   11    READ(1,2000,END=12)LREC
 2000    FORMAT(1784A1)

         GO TO 14
   12    IEOF=IEOF+1
         WRITE(6,2001)IEOF
 2001    FORMAT(' IEOF= ',I2)

C****************************************
C  DOUBLE END-OF-FILE MEANS END-OF-TAPE *
C****************************************

         IF(IEOF .EQ. 2)GO TO 999
         GO TO 11
 14      CONTINUE
         IREC=IREC+1
         IREC2=IREC2+1

         IF(IREC.EQ.25)WRITE(6,2010)IREC2,IF
 2010    FORMAT(' RECS READ=',I10,'    SEARCHING FOR SWATH ',I2)

         IF(IREC.EQ.25)IREC=0
         ITIME=INT44(KBT,LREC(1),LREC(2),LREC(3),LREC(4))
         REV=1.D-4*INT44(KBT,LREC(5),LREC(6),LREC(7),LREC(8))

         IF(ITIME.LT.STIME(IF))GO TO 10
         IF(ITIME.GT.ETIME(IF))GO TO 980

         CALL FDLTLN(ISCAN)

C*******************************
C   Scan (array platform) filter  *
C*******************************
         do 42 i=2,63
            ii = i*2-1
            call testreg (alat(ii), alon(ii), regions, reg_flg)

C**********************************************************************
C   If any of the elements are in the right spot, skip to output section   *
C**********************************************************************
            if (reg_flg) then i = 63
   42    continue

         CALL FDTA(ISCAN)
         IF(ISCAN .EQ. 2) GO TO 30

         CALL WINDMX(WIND,TB,RAINF)
         CALL GTLAT(GTL)             !Calculate ground track point latitude

         DO 20 I=2,63
```

```
                 II=I*2-1
                 do 101 j=1,11
                    if ((alat(ii) .gt. regions(j,1)) .and.
        *                (alat(ii) .lt. regions(j,2)) .and.
        *                (alon(ii) .gt. regions(j,3)) .and.
        *                (alon(ii) .lt. regions(j,4)))
        *              write (j+10, 2101) itime, alat(ii), alon(ii), tb(1,i),
        *                               tb(2,i), tb(5,i), tb(3,i), tb(4,i)
   101           continue
  2101           format (1X, 1I8, 2X, 1F6.2, 3X, 1F6.2, 3X, 5(2X,F6.2))
    20        CONTINUE

              GO TO 10
    30        CONTINUE

C*****************************************************
C  PRINT OUT THE 85GHZ DATA --> A-SCAN THEN B-SCAN *
C*****************************************************

              SC = 'A'
              II=1

              DO 40 I=1,64
                 WRITE(2,2200)ALAT(II),ALON(II),TAHI(1,I),TAHI(2,I),
        &        II,SC,ITOIL(1,I)
                 II=II+1
                 WRITE(2,2200)ALAT(II),ALON(II),TAHI(5,I),TAHI(6,I),
        &        II,SC,ITOIL(2,I)
                 II=II+1
    40        CONTINUE
              SC='B'
              II=1

              DO 50 I=1,64
                 WRITE(2,2200)BLAT(II),BLON(II),TAHI(3,I),TAHI(4,I),
        &        II,SC,ITOIL(3,I)
                 II=II+1
                 WRITE(2,2200)BLAT(II),BLON(II),TAHI(7,I),TAHI(8,I),
        &        II,SC,ITOIL(4,I)
                 II=II+1
    50        CONTINUE

  2200        FORMAT(4(X,F6.2),X,I3,A1,X,I2)
              GO TO 10
   980        CLOSE(2)
   990     CONTINUE
           KFLAG=1
   999     RETURN
           END
```

```
PROGRAM SECTIONS

    Name                                   Bytes   Attributes

  0 $CODE                                   1945   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  1 $PDATA                                   745   PIC CON REL LCL   SHR NOEXE   RD NOWRT QUAD
  2 $LOCAL                                  3236   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD
  3 INDATA                                  1796   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD
  4 OUTDAT                                  7156   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD

    Total Space Allocated                  14878

ENTRY POINTS

    Address   Type  Name

  0-00000000        SWATH

VARIABLES

    Address   Type  Name              Address    Type  Name              Address    Type  Name              Address    Type  Name

  4-00000018  R*4   ALTSC          2-00000AFD   CHAR DECIS           2-00000B0C  R*4   DUM               4-00000034  R*4   FRTEMP
  2-00000B30  R*4   GTL            2-00000B24   I*4  I               3-000006FC  I*4   IBYT              2-00000B20  I*4   IEOF
  2-00000B08  I*4   IERR           2-00000B18   I*4  IF              2-00000B04  I*4   IFILE             3-00000700  I*4   IFLAG
  2-00000B28  I*4   II             2-00000B10   I*4  IREC            2-00000B14  I*4   IREC2          AP-00000004@ I*4   ISCAN
  4-000001F0  I*4   ISPAR1         4-00000008   I*4  ITIME           4-0000000C  I*4   ITIMSC            2-00000B34  I*4   J
  3-000006F8  I*4   KBT         AP-00000008@   I*4  KFLAG           2-00000B00  L*4   REG_FLG           4-00000000  R*8   REV
  4-00000030  R*4   RFTEMP         2-00000AFC   CHAR SC              2-00000B2C  R*4   THENI             4-00000010  R*4   XLATSC
  4-00000014  R*4   XLONSC

ARRAYS

    Address   Type  Name                 Bytes  Dimensions

  4-000001F4  R*4   ALAT                   512  (128)
  4-000003F4  R*4   ALON                   512  (128)
  4-000005F4  R*4   BLAT                   512  (128)
  4-000007F4  R*4   BLON                   512  (128)
  4-0000006C  R*4   CALOFF                  28  (7)
  4-00000050  R*4   CALSLP                  28  (7)
  2-00000088  I*4   ETIME                   40  (10)
  2-00000A98  CHAR  FNAME                  100  (10)
  4-0000001C  R*4   HLTEMP                  12  (3)
  4-00000038  I*4   IAGC                    24  (6)
  4-00000088  I*4   ICOLDA                 140  (5, 7)
  4-000001A0  I*4   ICOLDB                  40  (5, 2)
  4-00000114  I*4   IHOTA                  140  (5, 7)
  4-000001C8  I*4   IHOTB                   40  (5, 2)
  4-00001AF4  I*4   ISPAR2                 256  (64)
  2-000001CC  I*4   ITNOW                   28  (7)
  4-000016F4  I*4   ITOIL                 1024  (4, 64)
  2-000001B0  I*4   ITREF                   28  (7)
  4-00000028  I*4   IVOLT                    8  (2)
```

```
2-00000000  I*4   JULIAN        96  (12, 2)
3-00000000  CHAR  LREC        1784  (1784)
2-00000C0B0 I*4   RAINF        256  (64)
2-000009E8  R*4   REGIONS      176  (11, 4)
2-0000C060  I*4   STIME         40  (10)
4-00000EF4  R*4   TAHI        2048  (8, 64)
4-000009F4  R*4   TALO        1280  (5, 64)
2-000002E8  R*4   TB          1792  (7, 64)
2-000001E8  R*4   WIND         256  (64)
```

LABELS

Address	Label	Address	Label	Address	Label	Address	Label	Address	Label	Address	Label
0-00000031	1	0-0000029F	10	0-000002A4	11	0-000002CB	12	0-000002F9	14	0-0000051E	20
0-00000528	30	0-00000649	40	0-000003D7	42	0-00000775	50	0-00000517	101	0-00000783	980
0-0000078C	990	0-00000798	999	1-000000C0	1000'	1-00000004	1010'	1-0000011E	1100'	1-0000014A	1200'
1-00000168	1300'	1-00000186	1400'	1-000001A1	1500'	1-000001A4	1550'	1-000001EF	1560'	1-00000204	1600'
1-0000024E	1700'	1-000001F2	1800'	1-0000027B	2000'	1-00000281	2001'	1-0000028D	2010'	1-000002B9	2101'
1-000002D4	2200'										

FUNCTIONS AND SUBROUTINES REFERENCED

Type	Name	Type	Name	Type	Name	Type	Name	Type	Name	Type	Name
	ESTREG		FDLTLN		FDTA		FOR$CLOSE		FOR$OPEN		GTLAT
I*4	INT44		OPENREG		QTIME		READHD		TESTREG		WINDMX

COMMAND QUALIFIERS

```
FORTRAN/NOOPT/DEBUG/LIST/NOOBJ SWATH

/CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
/DEBUG=(SYMBOLS,TRACEBACK)
/DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
/SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
/STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
/WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
/CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
/F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
/NOANALYSIS_DATA
/NODIAGNOSTICS
/LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]SWATH.LIS;1
/NOOBJECT
```

COMPILATION STATISTICS

```
Run Time:           2.10 seconds
Elapsed Time:       2.63 seconds
Page Faults:        692
Dynamic Memory:     484 pages
```

```
      subroutine testreg (lat, lon, regions, reg_flg)
C**********************************************************************
C   Subroutine TESTREG tests a set of lat/lon coordinates to determine   *
C   whether or not said coordinates fall within a specified region.  The *
C   regions in question are pre-defined and passed in via a 2-D array    *
C   for the third input parameter.  Since the application of this        *
C   routine is such that it will be called again and again to test       *
C   literally millions of coordinates, it has been tailored to conserve  *
C   cpu usage as much as possible, by implementing a "first pass"        *
C   criterion.  That is, the first time the coordinates in question      *
C   passes any of the conditions given in the routine, it assigns a      *
C   positive value to a logical variable and then terminates the         *
C   remaining comparisions.                                              *
C**********************************************************************

      real lat, lon, regions(11,4)
      logical reg_flg
      integer i

      reg_flg = .false.
      do 10 i=1,11
         if ((lat .gt. regions(i,1)) .and.
     *        (lat .lt. regions(i,2)) .and.
     *        (lon .gt. regions(i,3)) .and.
     *        (lon .lt. regions(i,4))) reg_flg = .true.
         if (reg_flg) then i = 11
   10 continue

      return
      end
```

```
PROGRAM SECTIONS

    Name                                     Bytes   Attributes

  0 $CODE                                       91   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                      52   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                      143


ENTRY POINTS

    Address   Type  Name

  0-00000000        TESTREG


VARIABLES

    Address   Type  Name              Address   Type  Name              Address   Type  Name              Address   Type  Name

  2-00000000  I*4   I            AP-00000004@ R*4   LAT            AP-00000008@ R*4   LON            AP-00000010@ L*4   REG_FLG
  2-00000004  R*4   THENI


ARRAYS

    Address   Type  Name                 Bytes  Dimensions

 AP-0000000C@ R*4   REGIONS               176  (11, 4)


LABELS

    Address    Label

  0-00000056   10


COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ TESTREG

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]TESTREG.LIS;1
  /NOOBJECT
```

```
COMPILATION STATISTICS

  Run Time:          0.40 seconds
  Elapsed Time:      0.93 seconds
  Page Faults:       449
  Dynamic Memory:    204 pages
```

```
      SUBROUTINE WINDMX( DMXWIN,TB,RAINF)

      REAL*4 C0(9),C1(9),C2(9),C3(9),C4(9)
      INTEGER*4 INDEX(12,8),JCHFX(7),RAINF(64)
      INTEGER*4 ITREF(7),JULIAN(12,2),ITNOW(7)
      REAL*4 TB(7,64),DMXWIN(64),APC(4,7)

C*********************************
C     SPECIFY COMMON /OUTDAT/    *
C*********************************

      REAL*8 REV
      INTEGER*4 ITIME,ITIMSC,IVOLT,IAGC,ICOLDA,IHOTA,ICOLDB,IHOTB,ISPAR1
      INTEGER*4 ITOIL,ISPAR2
      REAL*4 XLATSC,XLONSC,ALTSC,HLTEMP,RFTEMP,FRTEMP,CALSLP,CALOFF
      REAL*4 ALAT,ALON,BLAT,BLON,TALO,TAHI

      COMMON/OUTDAT/ REV,ITIME,ITIMSC,XLATSC,XLONSC,ALTSC,
     1 HLTEMP(3),IVOLT(2),RFTEMP,FRTEMP,IAGC(6),CALSLP(7),CALOFF(7),
     2 ICOLDA(5,7),IHOTA(5,7),ICOLDB(5,2),IHOTB(5,2),ISPAR1,
     3 ALAT(128),ALON(128),BLAT(128),BLON(128),
     4 TALO(5,64),TAHI(8,64),ITOIL(4,64),ISPAR2(64)

C**************************
C     INITIALIZE DATA     *
C**************************

      DATA ITREF/87,1,1,0,0,0,1/
      DATA JULIAN/1,32,60,91,121,152,182,213,244,274,305,335,
     &            1,32,61,92,122,153,183,214,245,275,306,336/
      DATA JCHFX/2,1,4,3,0,2,1/
      DATA APC/1.0471,0.0049,0.0073,0.0029,
     2         1.0472,0.0043,0.0080,0.0028,
     3         1.0422,0.0225,0.0032,0.0022,
     4         1.0428,0.0272,0.0010,0.0004,
     5         1.0513,0.0111,0.0080,0.0055,
     6         1.0341,0.0142,0.0040,0.0037,
     7         1.0359,0.0201,0.0027,0.0009/
      DATA SLP22H,OFF22H/0.653,96.6/
      DATA C0/191.56,168.39,177.315,147.76,127.13,163.07,
     1 95.994,130.42,117.59/
      DATA C1/.4903,.5366,.3913,.5077,.4788,.2923,.6106,.3676,.4225/
      DATA C2/-.4432,-.4548,-.2818,-.3547,-.2546,-.1204,
     1 -.3034,-.1580,-.1899/
      DATA C3/-.9199,-.7656,-1.0083,-.7409,-.7162,-1.0967,
     1 -.4638,-.8400,-.7096/
      DATA C4/.3577,.2635,.4095,.2333,.2030,.4612,.0192,.3056,.2081/
      DATA INDEX/ 9, 9, 9, 9, 8, 8, 8, 8, 8, 8, 9, 9,
     2            7, 7, 5, 5, 5, 6, 6, 6, 5, 5, 5, 7,
     3            4, 4, 4, 4, 4, 3, 3, 3, 3, 3, 3, 4,
     4            2, 2, 2, 2, 2, 1, 1, 1, 1, 1, 1, 2,
     5            1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 1,
     6            3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 4, 3,
     7            6, 6, 5, 5, 5, 7, 7, 7, 5, 5, 5, 6,
     8            8, 8, 8, 8, 9, 9, 9, 9, 9, 9, 8, 8/

C**************************
```

```
C      BEGIN EXECUTION    *
C*************************

C*****************************************************************
C   THE FIRST AND LAST PIXELS WE CANNOT COMPUTE TB OR WINDS FOR   *
C*****************************************************************

      DO 90 I=1,7
         TB(I,1)=999.99
         TB(I,64)=999.99
   90 CONTINUE

      RAINF(1)=0
      RAINF(2)=0
      DMXWIN(1)=99.99
      DMXWIN(64)=99.99
      CALL QTIME(ITREF,ITNOW,ITIME,IERR,2)
      JMON=ITNOW(2)

C*******************************
C     LOOP THRU CELLS IN SCAN    *
C*******************************

      DO 300 ICEL=2,63

C*********************************************************
C     COMPUTE TB'S, TB() = 19V,19H,37V,37H,21V,85V,85H    *
C*********************************************************

         DO 200 ICH=1,5
            JCH=JCHFX(ICH)
            IF(ICH.NE.5) TAXPOL=TALO(JCH,ICEL)
            IF(ICH.EQ.5) TAXPOL=OFF22H+SLP22H*TALO(2,ICEL)
            TBX=APC(1,ICH)*TALO(ICH,ICEL)-APC(2,ICH)*TAXPOL-
     1      APC(3,ICH)*TALO(ICH,ICEL-1)-APC(4,ICH)*TALO(ICH,ICEL+1)
            TB(ICH,ICEL)=0.1*INT(10.*TBX)
  200    CONTINUE

         DO 202 ICH=6,7
            JCH=JCHFX(ICH)
            TAXPOL=TAHI(JCH,ICEL)
            I=ICH-5
            TBX=APC(1,ICH)*TAHI(I,ICEL)-APC(2,ICH)*TAXPOL-
     1      APC(3,ICH)*TAHI(I,ICEL-1)-APC(4,ICH)*TAHI(I,ICEL+1)
            TB(ICH,ICEL)=0.1*INT(10.*TBX)
  202    CONTINUE

C*******************
C     CHECK TOIL    *
C*******************

         IF(ITOIL(1,ICEL).GE.4.AND.ITOIL(1,ICEL).LE.5) GO TO 203
         DMXWIN(ICEL)=31.
         RAINF(ICEL)=0
         GO TO 300
  203    CONTINUE
```

```
        DELTB=TB(3,ICEL)-TB(4,ICEL)

C***************************************
C     IF HEAVY RAIN SET WIND TO 31     *
C***************************************

        IF(DELTB .GT. 10)GO TO 205
        RAINF(ICEL)=2
        DMXWIN(ICEL)=31.
        GO TO 300

  205   IF(ITOIL(1,ICEL).EQ.5) GO TO 210

C************************
C     CHECK FOR ICE     *
C************************

        IF(TB(2,ICEL).GT.140..AND.DELTB.GT.5..AND.DELTB.LT.62)
     1  DMXWIN(ICEL)=31.
        IF(TB(2,ICEL).GT.140..AND.DELTB.GT.5..AND.DELTB.LT.62)
     1  GO TO 300

C*********************************************
C     PROCEED TO COMPUTE D-MATRIX WIND      *
C*********************************************

  210   CONTINUE
        RAINF(ICEL)=0
        JCEL=2*ICEL-1
        XLAT=ALAT(JCEL)
        ILAT=8
        IF(XLAT.GT.-55.) ILAT=7
        IF(XLAT.GT.-25.) ILAT=6
        IF(XLAT.GT.-20.) ILAT=5
        IF(XLAT.GT.  0.) ILAT=4
        IF(XLAT.GT. 20.) ILAT=3
        IF(XLAT.GT. 25.) ILAT=2
        IF(XLAT.GT. 55.) ILAT=1
        I=INDEX(JMON,ILAT)
        DMXWIN(ICEL)=C0(I)+C1(I)*TB(2,ICEL)+
     &  C2(I)*TB(5,ICEL)+C3(I)*TB(3,ICEL)+C4(I)*TB(4,ICEL)
        IF(DMXWIN(ICEL).GT.29.) DMXWIN(ICEL)=30.
        IF(DMXWIN(ICEL).LE.-2.) DMXWIN(ICEL)=30.
        IF(DMXWIN(ICEL).LT.0.) DMXWIN(ICEL)=0.
  300 CONTINUE
      RETURN
      END
```

```
PROGRAM SECTIONS

    Name                                Bytes   Attributes

  0 $CODE                                1065   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  1 $PDATA                                  4   PIC CON REL LCL   SHR NOEXE   RD NOWRT QUAD
  2 $LOCAL                               1044   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD
  3 OUTDAT                               7156   PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD

    Total Space Allocated                9269

ENTRY POINTS

    Address   Type  Name

  0-00000000        WINDMX

VARIABLES

    Address   Type  Name           Address   Type  Name          Address   Type  Name          Address   Type  Name

  3-00000018  R*4  ALTSC       2-00000380  R*4  DELTB       3-00000034  R*4  FRTEMP      2-00000360  I*4  I
  2-0000036C  I*4  ICEL        2-00000370  I*4  ICH         2-00000364  I*4  IERR        2-0000038C  I*4  ILAT
  3-000001F0  I*4  ISPAR1      3-00000008  I*4  ITIME       3-0000000C  I*4  ITIMSC      2-00000384  I*4  JCEL
  2-00000374  I*4  JCH         2-00000368  I*4  JMON        2-0000035C  R*4  OFF22H      3-00000000  R*8  REV
  3-00000030  R*4  RFTEMP      2-00000358  R*4  SLP22H      2-00000378  R*4  TAXPOL      2-0000037C  R*4  TBX
  2-00000388  R*4  XLAT        3-00000010  R*4  XLATSC      3-00000014  R*4  XLONSC

ARRAYS

    Address   Type  Name                 Bytes  Dimensions

  3-000001F4  R*4  ALAT                   512  (128)
  3-000003F4  R*4  ALON                   512  (128)
  2-000002E8  R*4  APC                    112  (4, 7)
  3-000005F4  R*4  BLAT                   512  (128)
  3-000007F4  R*4  BLON                   512  (128)
  2-00000000  R*4  C0                      36  (9)
  2-00000024  R*4  C1                      36  (9)
  2-00000048  R*4  C2                      36  (9)
  2-0000006C  R*4  C3                      36  (9)
  2-00000090  R*4  C4                      36  (9)
  3-0000006C  R*4  CALOFF                  28  (7)
  3-00000050  R*4  CALSLP                  28  (7)
 AP-00000004@ R*4  DMXWIN                 256  (64)
  3-0000001C  R*4  HLTEMP                  12  (3)
  3-00000038  I*4  IAGC                    24  (6)
  3-00000038  I*4  ICOLDA                 140  (5, 7)
  3-000001A0  I*4  ICOLDB                  40  (5, 2)
  3-00000114  I*4  IHOTA                  140  (5, 7)
  3-000001C8  I*4  IHOTB                   40  (5, 2)
  2-000000B4  I*4  INDEX                  384  (12, 8)
  3-00001AF4  I*4  ISPAR2                 256  (64)
  2-000002CC  I*4  ITNOW                   28  (7)
```

```
   3-000016F4  I*4   ITOIL            1024  (4, 64)
   2-00000250  I*4   ITREF              28  (7)
   3-00000028  I*4   IVOLT               8  (2)
   2-00000234  I*4   JCHFX              28  (7)
   2-0000026C  I*4   JULIAN             96  (12, 2)
  AP-000000C@  I*4   RAINF             256  (64)
   3-00000EF4  R*4   TAHI             2048  (8, 64,
   3-000009F4  R*4   TALO             1280  (5, 64)
  AP-00000008@ R*4   TB               1792  (7, 64)
```

LABELS

Address	Label	Address	Label	Address	Label	Address	Label	Address	Label	Address	Label
0-00000050	90	0-00000152	200	0-00000200	202	0-0000023E	203	0-00000279	205	0-000002E0	210
0-00000421	300										

FUNCTIONS AND SUBROUTINES REFERENCED

```
  Type  Name

        QTIME
```

```
C******************************************
```

COMMAND QUALIFIERS

```
  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ WINDMX

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RDSSMI]WINDMX.LIS;1
  /NOOBJECT
```

COMPILATION STATISTICS

```
  Run Time:            1.70 seconds
  Elapsed Time:        2.23 seconds
  Page Faults:         617
  Dynamic Memory:      444 pages
```

```
      program rainrate
c*********************************************************************
c   Program RAINRATE computes the rate of rainfall at a specified location *
c   given the appropriate microwave imagery data.                          *
c                                                                          *
c   Writen by:  James S. Belfiore, Jr.                                     *
c               Atmospheric and Environmental Research, Inc.               *
c               840 Memorial Drive                                         *
c               Cambridge, MA 02139                                        *
c               (617)-547-6207                                             *
c                                                                          *
c*********************************************************************
c                                                                          *
c   Program Variables:         lat - latitude of point in question        *
c                              lon - longitude of point in question       *
c                             rate - rate of precipitation                *
c                             t19h - 19 Ghz (horizontal) brightness temp  *
c                             t19v - 19 Ghz (vertical) brightness temp    *
c                             t22v - 22 Ghz (vertical) brightness temp    *
c                             t37h - 37 Ghz (horizontal) brightness temp  *
c                             t37v - 37 Ghz (vertical) brightness temp    *
c                                i - counter                              *
c                                j - counter                              *
c                             ieof - End of File warning flag             *
c                             time - SSM/I data timestamp                 *
c                                                                          *
c*********************************************************************
c                                                                          *
c   Functions and                                                          *
c   Subroutines called:    openreg - opens regions of interest files      *
c                         openrain - opens rain data files                *
c                        rain_land - computes rain rates over land        *
c                                                                          *
c*********************************************************************

      real lat, lon, t19h, t19v, t22v, t37h, t37v, rate
      real rain_land
      integer i, j, ieof, time

c*********************************
c   Open input and output files  *
c*********************************
      call openreg ()
      call openrain ()

c*****************************************************************
c   Loop through files, and data therein: check and compute rainfall  *
c*****************************************************************
      do 10, i=11,21
         do 20, j=1,10000
            read (i, 100, iostat=ieof) time, lat, lon, t19v,
     *                                 t19h, t22v, t37v, t37h
            if (ieof .lt. 0) then
               go to 10
            endif

            if (((t22v - t19v) .le. 4.0) .and.
```

```
      *           (((t19v+t37v)/2) - ((t19h+t37h)/2) .le. 4.0) .and.
      *           (t19v .gt. 262.0)) then
                 rate = rain_land (t19h, t19v, t22v, t37h, t37v)

                 if (rate .lt. 0.0) then
                    write (i+11,150) time, lat, lon, 0.0
                 else
                    write (i+11,150) time, lat, lon, rate
                 endif

              else
                 write (i+11,150) time, lat, lon, 0.0
              endif

   20      continue
   10   ieof = 0
        continue

C**************
C   Formats   *
C**************
  100 format (1X, 1I8, 2X, 1F6.2, 3X, 1F6.2, 3X, 5(2X,F6.2))
  150 format (1X, 1I8, 2X, 1F6.2, 3X, 1F6.2, 3X, 1F10.4)

        end
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	455	PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $PDATA	51	PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL	92	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
Total Space Allocated	598	

ENTRY POINTS

Address	Type	Name
0-00000000		RAINRATE

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name	Address	Type	Name
2-00000020	I*4	I	2-00000028	I*4	IEOF	2-00000024	I*4	J	2-00000000	R*4	LAT
2-00000004	R*4	LON	2-0000001C	R*4	RATE	2-00000008	R*4	T19H	2-0000000C	R*4	T19V
2-00000010	R*4	T22V	2-00000014	R*4	T37H	2-00000018	R*4	T37V	2-0000002C	I*4	TIME

```
LABELS

  Address     Label       Address     Label       Address     Label       Address     Label

 0-000001B9   10         0-000001AE   20         1-00000004   100'       1-0000001F   150'

FUNCTIONS AND SUBROUTINES REFERENCED

 Type  Name             Type  Name             Type  Name

       OPENRAIN               OPENREG           R*4  RAIN_LAND

COMMAND QUALIFIERS

 FORTRAN/NOOPT/DEBUG/LIST/NOOBJ RAINRATE

 /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
 /DEBUG=(SYMBOLS,TRACEBACK)
 /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
 /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
 /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
 /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
 /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
 /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
 /NOANALYSIS_DATA
 /NODIAGNOSTICS
 /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RAINRATE]RAINRATE.LIS;1
 /NOOBJECT

COMPILATION STATISTICS

 Run Time:           0.62 seconds
 Elapsed Time:       1.37 seconds
 Page Faults:        494
 Dynamic Memory:     360 pages
```

```
      subroutine openrain ()
C*****************************************************************
C   Subroutine OPENRAIN opens the output files necessary to keep track  *
C   of the regional rainfall data processed from the SSM/I data tape in *
C   question.                                                           *
C*****************************************************************

      open (22, status='unknown', file='Lenigrad_rain.dat')
      open (23, status='unknown', file='Kiev_rain.dat')
      open (24, status='unknown', file='Simferopol_rain.dat')
      open (25, status='unknown', file='Moscow_rain.dat')
      open (26, status='unknown', file='Murmansk_rain.dat')
      open (27, status='unknown', file='Perm_rain.dat')
      open (28, status='unknown', file='Aktyubinsk_rain.dat')
      open (29, status='unknown', file='Tashkent_rain.dat')
      open (30, status='unknown', file='Semipalatinsk_rain.dat')
      open (31, status='unknown', file='Chita_rain.dat')
      open (32, status='unknown', file='Blagoveschensk_rain.dat')

      return
      end
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	105	PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $PDATA	200	PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL	352	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
Total Space Allocated	657	

ENTRY POINTS

Address	Type	Name
0-00000000		OPENRAIN

FUNCTIONS AND SUBROUTINES REFERENCED

Type	Name
	FOR$OPEN

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ OPENRAIN

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RAINRATE]OPENRAIN.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:          0.29 seconds
  Elapsed Time:      0.85 seconds
  Page Faults:       359
  Dynamic Memory:    200 pages
```

```
      function rain_land (t19v, t19h, t22v, t37v, t37h)
C*********************************************************************
C   Function LANDRAIN determines the rate of rainfall over a land mass  *
C   utilizing the collocated SSM/I brightness temperature measurements. *
C   This algorithm is taken directly from Olson et al (1990).           *
C                                                                       *
C   Note: This algorithm determines the rate of rainfall, independent   *
C         of the 85 Ghz brightness temperatures.                        *
C*********************************************************************

      real t19v, t19h, t22v, t37v, t37h
      real exp_term, term1, term2, term3, term4, term5

      term1 = 0.08150 * t37v
      term2 = 0.01638 * t37h
      term3 = 0.03561 * t22v
      term4 = 0.05079 * t19v
      term5 = 0.01875 * t19h

      exp_term = (1.32526 - term1 + term2 + term3 + term4 - term5)

      rain_land = (exp (exp_term) - 8.0)

      return
      end
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	104	PIC CON REL LCL SHR EXE RD NOWRT QUAD
2 $LOCAL	28	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
Total Space Allocated	132	

ENTRY POINTS

Address	Type	Name
0-00000000	R*4	RAIN_LAND

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name	Address	Type	Name
2-00000004	R*4	EXP_TERM	AP-00000008@	R*4	T19H	AP-00000004@	R*4	T19V	AP-0000000C@	R*4	T22V
AP-00000014@	R*4	T37H	AP-00000010@	R*4	T37V	2-00000008	R*4	TERM1	2-0000000C	R*4	TERM2
2-00000010	R*4	TERM3	2-00000014	R*4	TERM4	2-00000018	R*4	TERM5			

```
FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name

   R*4  MTH$EXP


COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ RAIN_LAND

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RAINRATE]RAIN_LAND.LIS;1
  /NOOBJECT


COMPILATION STATISTICS

  Run Time:           0.32 seconds
  Elapsed Time:       0.85 seconds
  Page Faults:        393
  Dynamic Memory:     188 pages
```

```
      program rainavg
C***********************************************************************
C   Program RAINAVG takes data generated from the RAINRATE program, and  *
C   determines the following:                                          *
C                                                                      *
C          -   Spatial average of rainfall (per site, per pass)        *
C                                                                      *
C***********************************************************************

      integer arrcnt, pntcnt, ieof, time, prevtime
      real lat, lon, rainrate, ratearr(500,500)

      call openrain ()
      call openavg ()

      do 10, j=1,11
         ieof = 0
         prevtime = 0
         pntcnt = 1         ! Point Counter
         arrcnt = 0         ! Array Counter
         do 15, i=1,5000
            read (21+j, 100, iostat=ieof) time, lat, lon, rainrate
            if (ieof .lt. 0) then
               go to 15
            endif

C**********************************
C   Load rainrate and time arrays  *
C**********************************
            if ((time - prevtime) .lt. 600) then
               pntcnt = pntcnt + 1
               ratearr(arrcnt,pntcnt) = rainrate
            else
               if (arrcnt .gt. 0) then
                  call average (prevtime, ratearr, arrcnt, pntcnt, 32+j)
               endif
               pntcnt = 1
               arrcnt = arrcnt + 1
               ratearr(arrcnt,pntcnt) = rainrate
            endif

            prevtime = time
   15    continue
         call average (prevtime, ratearr, arrcnt, pntcnt, 32+j)
   10 continue

C************
C   Formats  *
C************
  100 format (1X, 1I8, 2X, 1F6.2, 3X, 1F6.2, 3X, 1F10.4)

      end
```

```
PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                   268   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  1 $PDATA                                   20   PIC CON REL LCL   SHR NOEXE   RD NOWRT QUAD
  2 $LOCAL                              1000108   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated               1000396

ENTRY POINTS

    Address   Type  Name

  0-00000000        RAINAVG

VARIABLES

    Address   Type  Name              Address   Type  Name              Address   Type  Name              Address   Type  Name

  2-000F4240  I*4   ARRCNT          2-000F4264  I*4   I               2-000F4248  I*4   IEOF            2-000F4260  I*4   J
  2-000F4254  R*4   LAT             2-000F4258  R*4   LON             2-000F4244  I*4   PNTCNT          2-000F4250  I*4   PREVTIME
  2-000F425C  R*4   RAINRATE        2-000F424C  I*4   TIME

ARRAYS

    Address   Type  Name                Bytes  Dimensions

  2-00000000  R*4   RATEARR           1000000  (500, 500)

LABELS

    Address   Label        Address   Label        Address   Label

  0-00000101  10         0-000000E2  15         1-00000000  100'

FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name              Type  Name              Type  Name

        AVERAGE                 OPENAVG                 OPENRAIN
```

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ RAINAVG

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RAINAVG]RAINAVG.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:          0.52 seconds
  Elapsed Time:      0.95 seconds
  Page Faults:       502
  Dynamic Memory:    344 pages
```

```
      subroutine average (time, array2d, ar_index, numpts, filecnt)
C************************************************************************
C   Subroutine AVERAGE is an averaging routine customed for the RAINAVG  *
C   program.  It takes the two dimensional array 'array2d' and averages  *
C   the values for a given data array of specified array index.          *
C                                                                        *
C   26-Jun-1990: The subroutine has been modified to determine the       *
C                standard deviation for each average.                    *
C************************************************************************
      integer ar_index, time, numpts, filecnt
      real array2d(500,500), arr_total, arr_avg, days, var_tot
      real variance, std_dev

      arr_avg = 0.0
      arr_total = 0.0
      do 10, i=1,numpts
         arr_total = arr_total + array2d(ar_index,i)
   10 continue

C**********************
C   Compute Average   *
C**********************
      arr_avg = arr_total / floatj(numpts)
      days = earth_time(time)

C***********************
C   Compute Variance   *
C***********************
      var_tot = 0.0
      do 15, i=1,numpts
         var_tot = var_tot + ((array2d(ar_index,i) - arr_avg)**2)
   15 continue
      variance = 0.0
      if (numpts .gt. 1) then
         variance = var_tot / (floatj(numpts) - 1)
      endif

C************************ ********
C   Compute Standard Deviation   *
C*********************************
      std_dev = 0.0
      if (variance .gt. 0.0) then
         std_dev = sqrt(variance)
      endif

C************************
C   Write our results   *
C************************
      write (filecnt,100) time, days, arr_avg, std_dev, numpts

C*************
C   Formats  *
C*************
  100 format (1X, 1I8, 2X, 1F16.8, 2X, 1F10.4, 2X, 1F10.4, 2X, 1I4)

      return
      end
```

```
PROGRAM SECTIONS

    Name                                    Bytes   Attributes

  0 $CODE                                     261   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  1 $PDATA                                     24   PIC CON REL LCL   SHR NOEXE   RD NOWRT QUAD
  2 $LOCAL                                     88   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                     373

ENTRY POINTS

    Address   Type  Name

  0-00000000        AVERAGE

VARIABLES

    Address   Type  Name                Address   Type  Name                Address   Type  Name                Address   Type  Name

  2-00000004  R*4   ARR_AVG           2-00000000  R*4   ARR_TOTAL        AP-0000000C@ I*4   AR_INDEX          2-00000008  R*4   DAYS
 AP-00000014@ I*4   FILECNT           2-00000018  I*4   I                AP-00000010@ I*4   NUMPTS            2-00000014  R*4   STD_DEV
 AP-00000004@ I*4   TIME              2-00000010  R*4   VARIANCE          2-0000000C  R*4   VAR_TOT

ARRAYS

    Address   Type  Name                Bytes  Dimensions

 AP-00000008@ R*4   ARRAY2D            1000000  (500, 500)

LABELS

    Address    Label        Address    Label        Address    Label

  0-0000003D   10         0-00000089   15         1-00000000   100'

FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name           Type  Name

   R*4  EARTH_TIME      R*4  MTH$SQRT
```

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ AVERAGE

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RAINAVG]AVERAGE.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:            0.54 seconds
  Elapsed Time:        0.97 seconds
  Page Faults:         541
  Dynamic Memory:      360 pages
```

```
        function earth_time(sat_time)
C*******************************************************************
C   Function EARTH_TIME computes the decimal number of days elapsed since   *
C   01-Jun-1989, 00:00 hours (GMT).  The input is the mission elapsed time   *
C   in seconds, from the SSM/I sensor array switch on.                      *
C*******************************************************************
        integer sat_time
        real elaps_time

        elaps_time = sat_time - 76204800
        earth_time = elaps_time / 86400.0

        return
        end
```

```
PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                    35   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                    8   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                    43

ENTRY POINTS

    Address   Type  Name

  0-00000000  R*4   EARTH_TIME

VARIABLES

    Address   Type  Name                 Address   Type  Name

  2-00000004  R*4   ELAPS_TIME      AP-00000004@ I*4   SAT_TIME

COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ EARTH_TIME

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RAINAVG]EARTH_TIME.LIS;1
```

```
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:             0.22 seconds
  Elapsed Time:         0.70 seconds
  Page Faults:          384
  Dynamic Memory:       188 pages
```

```
      subroutine openavg ()
C*********************************************************************
C   Subroutine OPENAVG opens the output files necessary to keep track  *
C   of the regional rainfall averages processed from RAINRATE program  *
C   data run in question.                                              *
C*********************************************************************

      open (33, status='unknown', file='Lenigrad_avg.dat')
      open (34, status='unknown', file='Kiev_avg.dat')
      open (35, status='unknown', file='Simferopol_avg.dat')
      open (36, status='unknown', file='Moscow_avg.dat')
      open (37, status='unknown', file='Murmansk_avg.dat')
      open (38, status='unknown', file='Perm_avg.dat')
      open (39, status='unknown', file='Aktyubinsk_avg.dat')
      open (40, status='unknown', file='Tashkent_avg.dat')
      open (41, status='unknown', file='Semipalatinsk_avg.dat')
      open (42, status='unknown', file='Chita_avg.dat')
      open (43, status='unknown', file='Blagoveschensk_avg.dat')

      return
      end
```

```
PROGRAM SECTIONS

    Name                                   Bytes   Attributes

  0 $CODE                                    105   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  1 $PDATA                                   189   PIC CON REL LCL   SHR NOEXE   RD NOWRT QUAD
  2 $LOCAL                                   352   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                    646

ENTRY POINTS

    Address   Type  Name

  0-00000000        OPENAVG

FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name

        FOR$OPEN
```

```
COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ OPENAVG

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.RAINAVG]OPENAVG.LIS;1
  /NOOBJECT


COMPILATION STATISTICS

  Run Time:             0.35 seconds
  Elapsed Time:         0.76 seconds
  Page Faults:          359
  Dynamic Memory:       200 pages
```

```
      program ilwc_tot

      integer i, time, numpts
      logical wrif
      real avg_rate, days
      real std_dev
      real*4 ilwc
      real*4 mm, zm, zt

      write (*,*) ' Enter Cloud Top (m): '
      read (*,*) zt
      write (*,*) ' Enter Cloud Height of Maximum LWC (m): '
      read (*,*) zm
      write (*,*) ' Enter Maximum LWC (units): '
      read (*,*) mm

      open (1, file='[.rawdata]blagoveschensk_tot.dat',
     *               status='unknown')  ! - Tot file
      open (2, file='blagoveschensk_ilwc.dat',
     *               status='unknown')  ! - Ilwc file

      do 10, i=1,161
         read (1,100) time, days, avg_rate, std_dev, numpts
         if (abs(avg_rate) .ge. 1.5) then
            call ilwc_conv (zm, zt, mm, avg_rate, ilwc, wrif)
         else
            call ilwc_strat (zm, zt, mm, avg_rate, ilwc, wrif)
         endif

         if (wrif) then
            write (2 110) days, ilwc
         endif

   10 continue

      rewind (1)
      open (3, file='blagoveschensk_conv.dat', status='unknown')
      open (4, file='blagoveschensk_strat.dat', status='unknown')

      do 15 i=1,161
         read (1,100) time, days, avg_rate, std_dev, numpts
         call ilwc_conv (zm, zt, mm, avg_rate, ilwc, wrif)
         if (wrif) then
            write (3,110) days, ilwc
         endif
         call ilwc_strat (zm, zt, mm, avg_rate, ilwc, wrif)
         if (wrif) then
            write (4,110) days, ilwc
         endif
   15 continue

  100 format (1X, 1I8, 2X, 1F16.8, 2X, 1F10.4, 2X, 1F10.4, 2X, 1I4)
  110 format (1X, 1F16.8, 2X, 1F16.4)

      end
```

```
PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                   578   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  1 $PDATA                                  231   PIC CON REL LCL   SHR NOEXE   RD NOWRT QUAD
  2 $LOCAL                                  308   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                  1117

ENTRY POINTS

    Address   Type  Name

  0-00000000        ILWC_TOT

VARIABLES

    Address   Type  Name                Address   Type  Name                Address   Type  Name                Address   Type  Name

  2-00000010  R*4   AVG_RATE          2-00000014  R*4   DAYS              2-00000000  I*4   I                 2-0000001C  R*4   ILWC
  2-00000020  R*4   MM                2-00000008  I*4   NUMPTS            2-00000018  R*4   STD_DEV           2-00000004  I*4   TIME
  2-0000000C  L*4   WRIF              2-00000024  R*4   ZM                2-00000028  R*4   ZT

LABELS

    Address   Label      Address   Label      Address   Label      Address   Label

  0-00000156  10       0-00000234  15       1-000000C4  100'     1-000000DC  110'

FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name            Type  Name            Type  Name

        FOR$OPEN              ILWC_CONV             ILWC_STRAT

COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ ILWC_TOT

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.ILWC]ILWC_TOT.LIS;1
  /NOOBJECT
```

```
COMPILATION STATISTICS

  Run Time:             0.71 seconds
  Elapsed Time:         1.18 seconds
  Page Faults:          497
  Dynamic Memory:       360 pages
```

```
      subroutine ilwc_conv (zm, zt, mm, avg_rate, ilwc, wrif)

      logical wrif
      real avg_rate
      real*4 cst_a, cst_a1, cst_a2, cst_a3, cst_a4
      real*4 cst_b, cst_b1, cst_b2, cst_b3, cst_b4
      real*4 cst_c, cst_c1, cst_c2, cst_c3, cst_c4
      real*4 cst_d
      real*4 ilwc
      real*4 mm, ms, zm, zt
      real*4 term_1, term_2, term_3, term_4, term_5

      if (avg_rate .eq. 0.0) then
         wrif = .false.
         return
      endif

      wrif = .true.
      ms = 0.07 * (avg_rate**0.83)

      cst_a1 = 1.0/ (((zm**5)*(zt**2)) - (2.*(zm**4)*(zt**3))
     *                  + ((zm**3)*(zt**4)))
      cst_a2 = ((3.*((zm)*(zt**2))) - (2.*(zt**3)) - (zm**3))*ms
      cst_a3 = ((3.*((zm)*(zt**2))) - (2.*(zt**3)))*mm
      cst_a4 = cst_a2 - cst_a3
      cst_a = cst_a1 * cst_a4

      cst_b1 = -1. * cst_a1
      cst_b2 = ((4.*((zm**2)*(zt**2))) - (2.*(zt**4)) -
     *           (2.*(zm**4)))*ms
      cst_b3 = ((4.*((zm**2)*(zt**2))) - (2.*(zt**4)))*mm
      cst_b4 = cst_b2 - cst_b3
      cst_b = cst_b4 * cst_b1

      cst_c1 = -1.0/ (((zm**4)*(zt**2)) - (2.*(zm**3)*(zt**3))
     *                  + ((zm**2)*(zt**4)))
      cst_c2 = ((zm**4) - (4.0*zm*(zt**3)) + (3.0*(zt**4)))*ms
      cst_c3 = ((4.0*zm*(zt**3)) - (3.0*(zt**4)))*mm
      cst_c4 = cst_c2 + cst_c3
      cst_c = cst_c1 * cst_c4

      cst_d = ms

      term_1 = (cst_a/5.0) * (zt**5)
      term_2 = (cst_b/4.0) * (zt**4)
      term_3 = (cst_c/3.0) * (zt**3)
      term_4 = (cst_d) * (zt)
      term_5 = ms

      ilwc = term_1 + term_2 + term_3 + term_4 + term_5

      return
      end
```

```
PROGRAM SECTIONS

    Name                                   Bytes   Attributes

  0 $CODE                                    680   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                    88   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                    768

ENTRY POINTS

    Address   Type  Name

  0-00000000        ILWC_CONV

VARIABLES

    Address   Type  Name             Address   Type  Name             Address   Type  Name             Address   Type  Name

 AP-00000010@ R*4   AVG_RATE        2-00000000  R*4  CST_A            2-00000004  R*4  CST_A1           2-00000008  R*4  CST_A2
  2-0000000C  R*4   CST_A3          2-00000010  R*4  CST_A4           2-00000014  R*4  CST_B            2-00000018  R*4  CST_B1
  2-0000001C  R*4   CST_B2          2-00000020  R*4  CST_B3           2-00000024  R*4  CST_B4           2-00000028  R*4  CST_C
  2-0000002C  R*4   CST_C1          2-00000030  R*4  CST_C2           2-00000034  R*4  CST_C3           2-00000038  R*4  CST_C4
  2-0000003C  R*4   CST_D          AP-00000014@ R*4  ILWC            AP-0000000C@ R*4  MM               2-00000040  R*4  MS
  2-00000044  R*4   TERM_1          2-00000048  R*4  TERM_2           2-0000004C  R*4  TERM_3           2-00000050  R*4  TERM_4
  2-00000054  R*4   TERM_5         AP-00000018@ L*4  WRIF            AP-00000004@ R*4  ZM              AP-00000008@ R*4  ZT

COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ ILWC_CONV

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.ILWC]ILWC_CONV.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:          0.88 seconds
  Elapsed Time:      1.27 seconds
  Page Faults:       454
  Dynamic Memory:    360 pages
```

```
      subroutine ilwc_strat (zm, zt, mm, avg_rate, ilwc)

      logical wrif
      real avg_rate
      real std_dev
      real*4 cst_a, cst_a1, cst_a2, cst_a3, cst_a4
      real*4 cst_b, cst_b1, cst_b2, cst_b3, cst_b4
      real*4 cst_c, cst_c1, cst_c2, cst_c3, cst_c4
      real*4 cst_d
      real*4 ilwc
      real*4 mm, ms, zm, zt
      real*4 term_1, term_2, term_3, term_4, term_5

      if (avg_rate .eq. 0.0) then
         wrif = .false.
         return
      endif

      wrif = .true.
      ms = 0.07 * (avg_rate**0.83)

      cst_a1 = -1.0/ ( (zm**2) * (zt) * ((zt - zm)**2) )
      cst_a2 = ((zt - zm)**2)*ms
      cst_a3 = (zt * (2.0 * zm - zt)) * mm
      cst_a4 = cst_a2 + cst_a3
      cst_a = cst_a1 * cst_a4

      cst_b1 = cst_a1
      cst_b2 = ((3.0*(zm**2)*zt) - (zt**3) - (2.0*(zm**3)))*ms
      cst_b3 = ((3.0*(zm**2)*zt) - (zt**3))*mm
      cst_b4 = cst_b2 - cst_b3
      cst_b = cst_b4 * cst_b1

      cst_c1 = -1.0/((zm*zt) * ((zt - zm)**2))
      cst_c2 = ((zm**3) - (3.0*zm*(zt**2)) + (2.0*(zt**3)))*ms
      cst_c3 = ((3.0*zm*(zt**2)) - (2.0*(zt**3)))*mm
      cst_c4 = cst_c2 + cst_c3
      cst_c = cst_c1 * cst_c4

      cst_d = ms

      term_1 = (cst_a/4.0) * (zt**4)
      term_2 = (cst_b/3.0) * (zt**3)
      term_3 = (cst_c/2.0) * (zt**2)
      term_4 = (cst_d) * (zt)
      term_5 = ms

      ilwc = term_1 + term_2 + term_3 + term_4 + term_5

      return
      end
```

```
PROGRAM SECTIONS

    Name                                  Bytes   Attributes

  0 $CODE                                   464   PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  2 $LOCAL                                   96   PIC CON REL LCL NOSHR NOEXE   RD   WRT QUAD

    Total Space Allocated                   560


ENTRY POINTS

    Address   Type  Name

  0-00000000        ILWC_STRAT


VARIABLES

    Address   Type  Name               Address   Type  Name              Address   Type  Name              Address   Type  Name

 AP-00000010@ R*4   AVG_RATE        2-00000008   R*4   CST_A          2-0000000C   R*4   CST_A1         2-00000010   R*4   CST_A2
  2-00000014  R*4   CST_A3          2-00000018   R*4   CST_A4         2-0000001C   R*4   CST_B          2-00000020   R*4   CST_B1
  2-00000024  R*4   CST_B2          2-00000028   R*4   CST_B3         2-0000002C   R*4   CST_B4         2-00000030   R*4   CST_C
  2-00000034  R*4   CST_C1          2-00000038   R*4   CST_C2         2-0000003C   R*4   CST_C3         2-00000040   R*4   CST_C4
  2-00000044  R*4   CST_D        AP-00000014@ R*4   ILWC        AP-0000000C@ R*4   MM             2-00000048   R*4   MS
  2-00000004  R*4   STD_DEV         2-0000004C   R*4   TERM_1         2-00000050   R*4   TERM_2         2-00000054   R*4   TERM_3
  2-00000058  R*4   TERM_4          2-0000005C   R*4   TERM_5         2-00000000   L*4   WRIF        AP-00000004@ R*4   ZM
 AP-00000008@ R*4   ZT


COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ ILWC_STRAT

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.ILWC]ILWC_STRAT.LIS;1
  /NOOBJECT


COMPILATION STATISTICS

  Run Time:            0.70 seconds
  Elapsed Time:        1.17 seconds
  Page Faults:         425
  Dynamic Memory:      216 pages
```

Appendix B Sample Output from the Tape Reading Algorithm

Time (Seconds)	Longitude (Degrees)	Latitude (Degrees)	Brightness Temperature (K) 19.35v	19.35h	22.235	37v	37h
86543433	55.68	38.46	270.60	266.80	270.40	269.50	265.90
86543433	55.81	38.79	272.40	269.30	271.40	269.70	266.70
86543433	55.93	39.13	272.10	269.30	271.20	270.50	267.60
86543437	55.02	37.48	271.10	268.80	271.60	269.40	266.50
86543437	55.17	37.78	270.80	268.20	270.80	269.30	266.10
86543437	55.31	38.08	270.00	265.10	271.40	268.40	264.30
86543437	55.46	38.39	271.10	264.50	269.30	267.40	263.30
86543437	55.59	38.72	271.60	267.50	270.10	269.60	266.60
86543437	55.71	39.06	271.50	268.60	272.00	269.30	266.00
86543440	54.80	37.42	271.90	268.70	270.60	268.60	265.40
86543440	54.95	37.72	271.90	268.60	271.60	269.30	266.20
86543440	55.09	38.02	271.50	267.60	269.70	268.30	266.00
86543440	55.24	38.33	271.00	264.90	269.10	267.60	264.00
86543440	55.37	38.66	270.50	265.60	270.20	267.90	263.40
86543440	55.49	39.00	271.90	268.60	270.30	269.10	266.00
86543444	54.58	37.36	271.60	268.20	269.10	268.10	264.90
86543444	54.73	37.66	271.20	268.20	269.90	268.50	264.70
86543444	54.87	37.96	271.20	267.70	269.90	268.50	266.10
86543444	55.02	38.26	271.20	265.90	268.10	268.10	264.90
86543444	55.15	38.59	270.60	265.20	269.60	267.80	262.90
86543444	55.27	38.93	270.90	266.80	270.00	268.80	264.90
86543448	54.35	37.30	270.30	266.70	268.70	267.60	264.80
86543448	54.50	37.60	271.10	266.90	267.60	267.90	266.00
86543448	54.65	37.90	271.40	267.80	270.40	268.80	264.80
86543448	54.80	38.20	270.30	267.30	269.90	267.60	264.40
86543448	54.93	38.53	270.00	264.90	268.10	267.10	263.30
86543448	55.05	38.86	270.40	264.70	269.80	266.90	262.80
86543448	55.18	39.19	270.90	266.00	269.30	268.30	265.10
86543452	54.28	37.54	269.80	266.70	268.50	267.20	263.70
86543452	54.43	37.83	270.40	266.20	268.30	268.10	264.90
86543452	54.58	38.13	270.40	267.20	270.40	268.40	264.90
86543452	54.71	38.46	269.70	264.90	268.30	267.20	262.70
86543452	54.83	38.79	268.80	263.60	268.70	266.90	262.00
86543452	54.96	39.12	269.70	263.40	268.50	266.90	261.70
86543456	54.21	37.77	270.10	266.60	268.40	266.40	262.80
86543456	54.36	38.07	270.30	266.30	269.90	267.30	264.40
86543456	54.49	38.39	270.20	265.70	270.10	266.90	264.40
86543456	54.61	38.72	269.10	264.30	268.20	265.60	262.10
86543456	54.74	39.05	269.20	263.80	269.00	266.60	261.80
86543459	54.27	38.33	270.20	265.70	268.80	267.10	263.00
86543459	54.39	38.66	269.30	264.00	268.40	266.80	263.50
86543459	54.52	38.98	269.00	263.70	268.00	266.40	262.50
86543463	54.17	38.59	269.60	264.50	267.40	266.50	262.00
86543463	54.30	38.91	269.70	264.30	267.60	266.30	262.50
86543467	54.20	39.17	269.80	266.00	268.10	267.30	264.20
86720726	57.73	39.10	267.70	264.20	264.90	264.20	262.80
86720730	57.70	38.66	266.20	263.70	267.30	265.60	264.30
86720730	57.52	38.93	267.50	265.20	267.50	265.40	263.20
86720730	57.34	39.18	267.20	264.50	266.80	263.70	261.30
86720733	57.68	38.22	264.70	259.80	264.00	263.80	260.50
86720733	57.50	38.48	267.60	264.50	267.30	266.40	265.20
86720733	57.32	38.75	268.30	265.50	267.30	265.50	264.00
86720733	57.14	39.00	267.80	264.90	266.00	265.40	263.20
86720737	57.63	37.74	263.50	258.70	264.50	261.80	259.70
86720737	57.47	38.04	263.50	258.00	264.90	262.50	257.20
86720737	57.29	38.30	267.50	264.60	265.70	266.80	264.90
86720737	57.11	38.57	268.30	265.20	267.40	266.00	265.10
86720737	56.93	38.82	267.10	263.70	266.50	264.30	261.20

Appendix C Mapping Software

```
      program where

C***********************************************************************
C   Program WHERE prompts the user for an elapsed time in the SSM/I data  *
C   mission (zero time defined as 00:07.31 - 01-June-1990), and a time    *
C   "window".  It then, via NCAR and GKS, projects a map of the world,    *
C   and superinposes the track of the satellite scanning platform at that *
C   time.                                                                 *
C***********************************************************************

      include 'sys$library:gksdefs.for'
      integer ws_id, linelim
      data ws_id /1/

      character*60 fname
      real lat, lon, rot, xmax, ymax
      real dlat, dlon, d1, d2, d3, d4, d5
      real dummys
      integer i, time, choice, prevtime
      integer ws_type, error, dummyi

      common /ws_vars/ ws_id, xmax, ymax, lat, lon

C*******************
C   Get data file   *
C*******************
      write (*,*) ' Enter file name (in quotes): '
      read (*,*) fname
      open (4, file=fname, status='unknown')
      read (4,150) time, lat, lon, d1, d2, d3, d4, d5
      rewind (4)

      write (*,*) ' Enter (1) for orthographic or (2) for cylindrical
     *equidistant projection:  '
      read (*,*) choice
      write (*,*) ' Enter number of lines to be read: '
      read (*,*) linelim

C*************
C   Open gks  *
C*************
      call gks$open_gks ('sys$error:')
      call gks$open_ws (ws_id, gks$k_conid_default,
     *                  gks$k_wstype_default)
      call gks$inq_ws_type (ws_id, error, dummys, ws_type, dummyi)
      call gks$inq_max_ds_size (ws_type, error, dummyi, xmax, ymax,
     *                          dummyi, dummyi)
      call gks$activate_ws (ws_id)

C**********************
C   Set color indices  *
C**********************
      Call SETUSV('IM',3)        ! 3 possible colors

      Call SETUSV('IR',1)               !RED
      Call SETUSV('IG',0)
      Call SETUSV('IB',0)
```

```
      Call SETUSV('IN',8000)
      Call GETUSV('II',I1)

      Call SETUSV('IR',2)               !Purple
      Call SETUSV('IG',0)
      Call SETUSV('IB',2)
      Call SETUSV('IN',8000)
      Call GETUSV('II',I2)

      Call SETUSV('IR',0)               !light BLUE
      Call SETUSV('IG',5)
      Call SETUSV('IB',7)
      Call SETUSV('IN',10000)
      Call GETUSV('II',I3)

C******************************
C   Define the map geometry    *
C******************************
      call map_geo (choice)

C******************
C   Draw the map  *
C******************
      Call MAPINT

C*****************************************************
C   Show continents and international boundaries    *
C*****************************************************
      Call MAPSTC('OU','PS')

C**************************************
C   Draw the latitude,longitude grid  *
C**************************************
      call SETUSV ('II', I2)
      call MAPLBL
      Call MAPGRD

C**************************************
C   draw the geographical boundaries  *
C**************************************
      call SETUSV ('II', I3)
      Call MAPLOT

C*************************
C   Draw the scan lines :  *
C   Set line color         *
C*************************
      Call SETUSV('II',I1)

      prevtime = 0
      call MAPIT(dlat,dlon,0)  ! pen up
      do 100, i = 1,linelim
         read (4,150) time, dlat, dlon, d1, d2, d3, d4, d5
         if (i .eq. 1) call MAPIT(dlat,dlon,0)
         if (prevtime .ne. time) call MAPIT(dlat,dlon,0)
         call MAPIT(dlat,dlon,1)  ! pen down
         call MAPIT(dlat,dlon,0)
```

```
                prevtime = time
       100 continue
       150 format (1X, I18, 2X, F6.2, 3X, F6.2, 5X, 5(F6.2,2X))

           call gks$update_ws (ws_id, gks$k_postpone_flag)
           call gks$update_ws (ws_id, gks$k_postpone_flag)
     c     pause

     C***************
     C   Close GKS  *
     C***************
           call gks$deactivate_ws (ws_id)
           call gks$close_ws (ws_id)
           call gks$close_gks

           END
```

PROGRAM SECTIONS

Name	Bytes	Attributes
0 $CODE	797	PIC CON REL LCL SHR EXE RD NOWRT QUAD
1 $PDATA	239	PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2 $LOCAL	832	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
3 WS_VARS	20	PIC OVR REL GBL SHR NOEXE RD WRT QUAD
Total Space Allocated	1888	

ENTRY POINTS

Address	Type	Name
0-00000000		WHERE

VARIABLES

Address	Type	Name	Address	Type	Name	Address	Type	Name	Address	Type	Name
2-0000006C	I*4	CHOICE	2-0000004C	R*4	D1	2-00000050	R*4	D2	2-00000054	R*4	D3
2-00000058	R*4	D4	2-0000005C	R*4	D5	2-00000044	R*4	DLAT	2-00000048	R*4	DLON
2-0000007C	I*4	DUMMYI	2-00000060	R*4	DUMMYS	2-00000078	I*4	ERROR	2-00000000	CHAR	FNAME
2-00000064	I*4	I	2-00000080	I*4	I1	2-00000084	I*4	I2	2-00000088	I*4	I3
3-0000000C	R*4	LAT	2-0000003C	I*4	LINELIM	3-00000010	R*4	LON	2-00000070	I*4	PREVTIME
2-00000040	R*4	ROT	2-00000068	I*4	TIME	3-00000000	I*4	WS_ID	2-00000074	I*4	WS_TYPE
3-00000004	R*4	XMAX	3-00000008	R*4	YMAX						

```
LABELS

    Address   Label       Address   Label

  0-000002E6  100       1-000000D4  150'


FUNCTIONS AND SUBROUTINES REFERENCED

  Type Name                        Type Name                        Type Name

       FOR$OPEN                         GETUSV                           GKS$ACTIVATE_WS
       GKS$CLOSE_GKS                    GKS$CLOSE_WS                     GKS$DEACTIVATE_WS
       GKS$INQ_MAX_DS_SIZE              GKS$INQ_WS_TYPE                  GKS$OPEN_GKS
       GKS$OPEN_WS                      GKS$UPDATE_WS                    MAPGRD
       MAPINT                           MAPIT                            MAPLBL
       MAPLOT                           MAPSTC                           MAP_GEO
       SETUSV


COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ WHERE

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.DISPLAY]WHERE.LIS;1
  /NOOBJECT


COMPILATION STATISTICS

  Run Time:           3.01 seconds
  Elapsed Time:       4.74 seconds
  Page Faults:        747
  Dynamic Memory:     560 pages
```

```
      subroutine ce_map

      common /ws_vars/ ws_id, xmax, ymax, lat, lon

      call gks$set_ws_viewport (ws_id, 0.0, xmax, 0.0, ymax)
      call gks$set_ws_window (ws_id, 0.0, 1.0, 0.25, 0.75)
      call gks$update_ws (ws_id, gks$k_perform_flag)

C********************************************
C   Use cylindrical equidistant projection   *
C********************************************
      Call MAPROJ('CE',0.0,0.0,0.0)

C****************************************************
C   Specify the angular distances to the edges of the map  *
C****************************************************
      call ma set('CO',90.,-180.,-90.,180.)

      return
      end
```

PROGRAM SECTIONS

	Name	Bytes	Attributes
0	$CODE	50	PIC CON REL LCL SHR EXE RD NOWRT QUAD
1	$PDATA	38	PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2	$LOCAL	124	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
3	WS_VARS	20	PIC OVR REL GBL SHR NOEXE RD WRT QUAD
	Total Space Allocated	232	

ENTRY POINTS

Address	Type	Name
0-00000000		CE_MAP

VARIABLES

Address	Type	Name	Address	Type	Name
2-00000000	R*4	GKS$K_PERFORM_FLAG	3-0000000C	I*4	LAT
3-00000010	I*4	LON	3-00000000	R*4	WS_ID
3-00000004	R*4	XMAX	3-00000008	R*4	YMAX

```
FUNCTIONS AND SUBROUTINES REFERENCED

  Type Name                          Type Name                          Type Name

       GKS$SET_WS_VIEWPORT                GKS$SET_WS_WINDOW                  GKS$UPDATE_WS
       MAPROJ                             MAPSET

COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ CE_MAP

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.DISPLAY]CE_MAP.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:           0.30 seconds
  Elapsed Time:       1.05 seconds
  Page Faults:        383
  Dynamic Memory:     200 pages
```

```
        subroutine or_map

        real left, right, bottom, top

        common /ws_vars/ ws_id, xmax, ymax, lat, lon

        call gks$set_ws_viewport (ws_id, 0.0, xmax, 0.0, ymax)
        call gks$set_ws_window (ws_id, 0.0, 1.0, 0.0, 1.0)
        call gks$update_ws (ws_id, gks$k_perform_flag)

C*****************************
C   Use a circular perimeter  *
C*****************************
c       Call MAPSTI ('EL',1)

C*********************************
C   Use orthographic projection   *
C*********************************
        Call MAPROJ ('OR', lat, lon, 23.0)

        write (*,*) ' Enter left, right, bottom, & top offset angles: '
        read (*,*) left, right, bottom, top
        call MAPSET ('AN', left, right, bottom, top)

        return
        end
```

PROGRAM SECTIONS

	Name	Bytes	Attributes
0	$CODE	133	PIC CON REL LCL SHR EXE RD NOWRT QUAD
1	$PDATA	67	PIC CON REL LCL SHR NOEXE RD NOWRT QUAD
2	$LOCAL	148	PIC CON REL LCL NOSHR NOEXE RD WRT QUAD
3	WS_VARS	20	PIC OVR REL GBL SHR NOEXE RD WRT QUAD
	Total Space Allocated	368	

ENTRY POINTS

Address	Type	Name
0-00000000		OR_MAP

VARIABLES

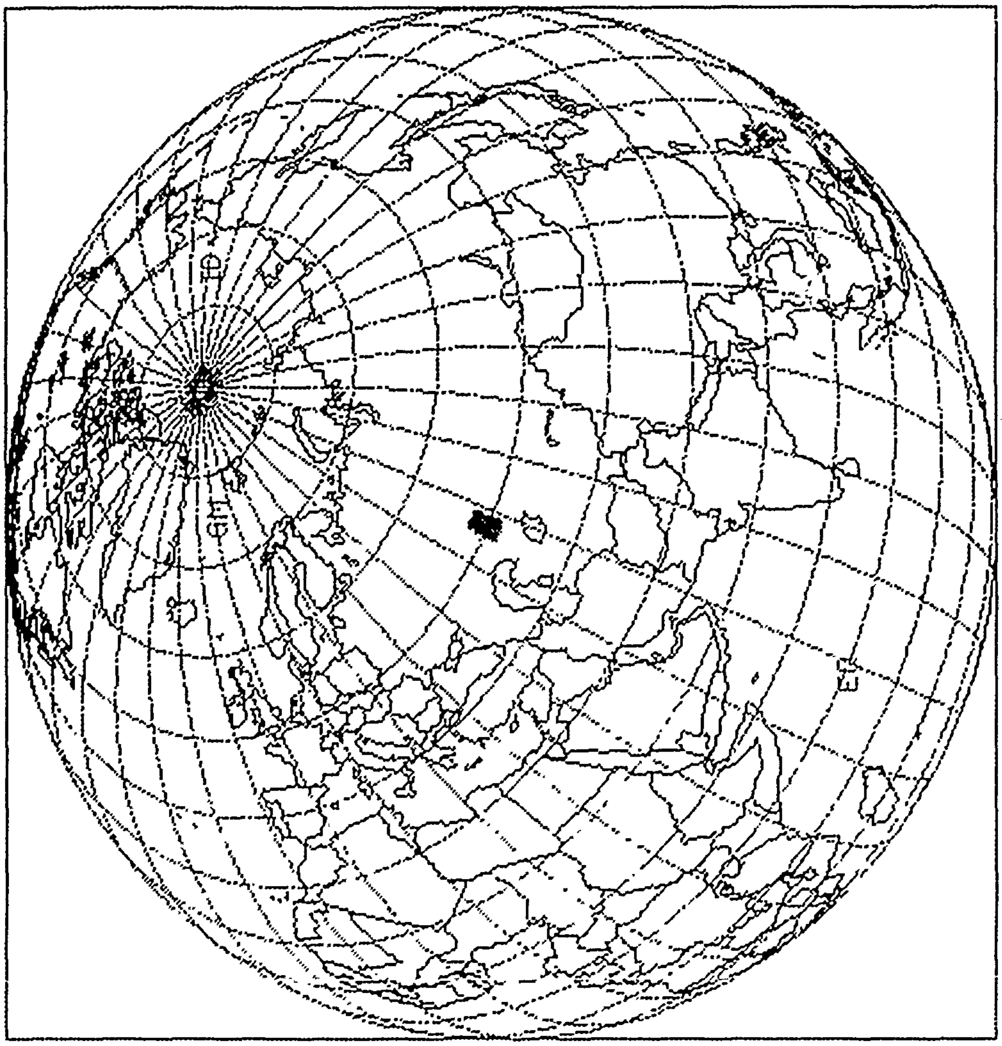
Address	Type	Name	Address	Type	Name
2-00000008	R*4	BOTTOM	2-00000010	R*4	GKS$K_PERFORM_FLAG
3-0000000C	I*4	LAT	2-00000000	R*4	LEFT
3-00000010	I*4	LON	2-00000004	R*4	RIGHT
2-0000000C	R*4	TOP	3-00000000	R*4	WS_ID

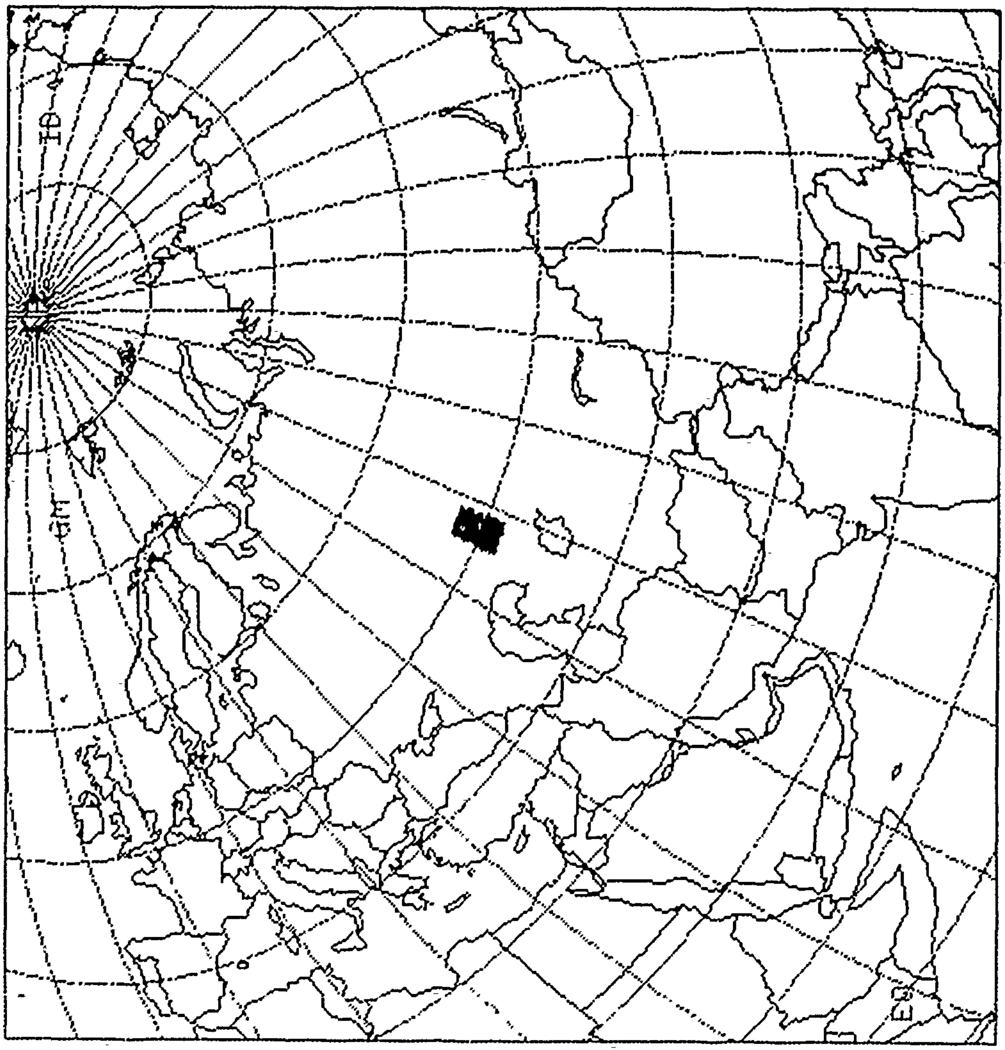
```
  3-00000004  R*4  XMAX                                      3-00000008  R*4  YMAX

FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name                              Type  Name                              Type  Name

        GKS$SET_WS_VIEWPORT                     GKS$SET_WS_WINDOW                       GKS$UPDATE_WS
        MAPROJ                                  MAPSET

COMMAND QUALIFIERS

  FORTRAN/NOOPT/DEBUG/LIST/NOOBJ OR_MAP

  /CHECK=(NOBOUNDS,OVERFLOW,NOUNDERFLOW)
  /DEBUG=(SYMBOLS,TRACEBACK)
  /DESIGN=(NOCOMMENTS,NOPLACEHOLDERS)
  /SHOW=(NODICTIONARY,NOINCLUDE,MAP,NOPREPROCESSOR,SINGLE)
  /STANDARD=(NOSEMANTIC,NOSOURCE_FORM,NOSYNTAX)
  /WARNINGS=(NODECLARATIONS,GENERAL,NOULTRIX,NOVAXELN)
  /CONTINUATIONS=19  /NOCROSS_REFERENCE  /NOD_LINES  /NOEXTEND_SOURCE
  /F77  /NOG_FLOATING  /I4  /NOMACHINE_CODE  /NOOPTIMIZE  /NOPARALLEL
  /NOANALYSIS_DATA
  /NODIAGNOSTICS
  /LIST=USER$DISK_26:[BELFIORE.SSMI.SRC.DISPLAY]OR_MAP.LIS;1
  /NOOBJECT

COMPILATION STATISTICS

  Run Time:           0.37 seconds
  Elapsed Time:       1.18 seconds
  Page Faults:        431
  Dynamic Memory:     200 pages
```

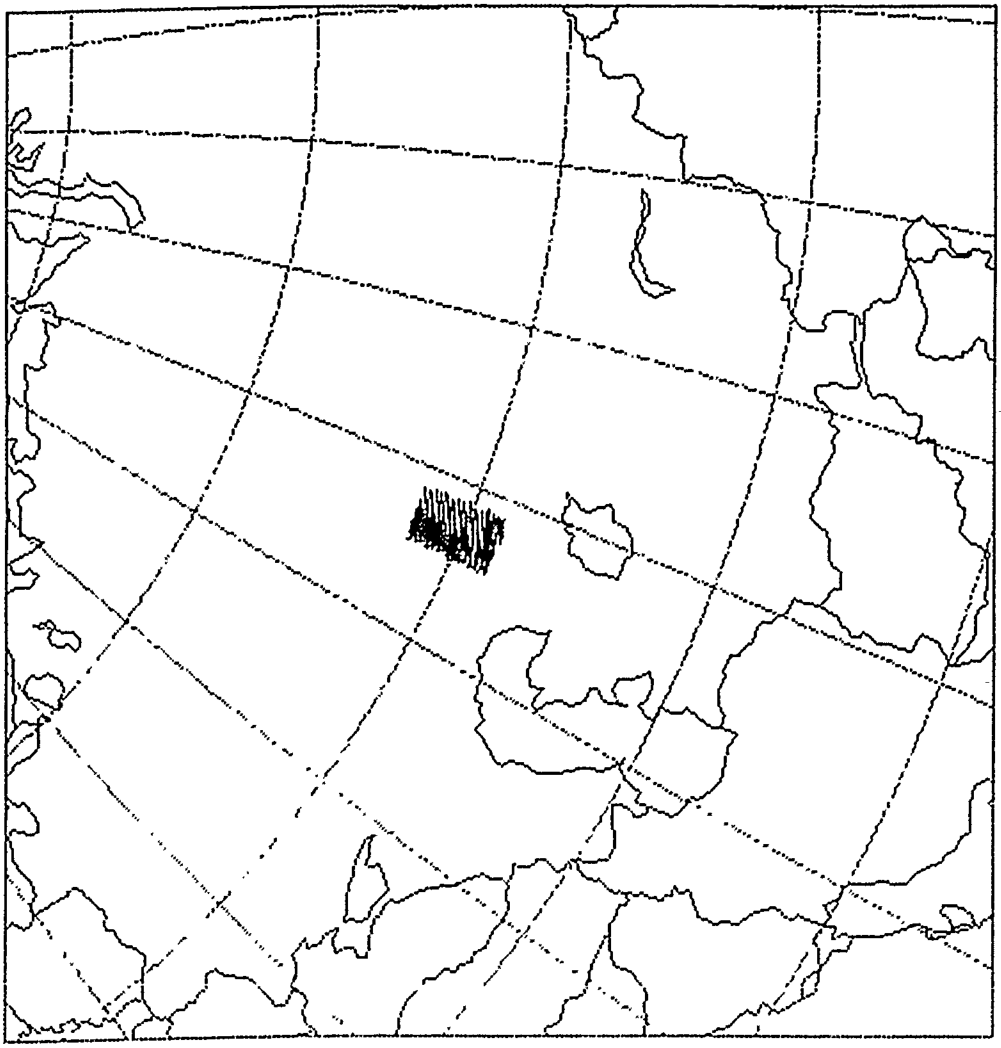
```
        subroutine map_geo (choice)

        integer choice

        common /ws_vars/ ws_id, xmax, ymax

        if (choice .eq. 1) call or_map
        if (choice .eq. 2) call ce_map

        return
        end
```

```
PROGRAM SECTIONS

    Name                                 Bytes   Attributes

  0 $CODE                                  29    PIC CON REL LCL   SHR   EXE   RD NOWRT QUAD
  3 WS_VARS                                12    PIC OVR REL GBL   SHR NOEXE   RD   WRT QUAD

    Total Space Allocated                  41


ENTRY POINTS

    Address   Type  Name

  0-00000000        MAP_GEO


VARIABLES

    Address   Type  Name           Address   Type  Name          Address   Type  Name          Address   Type  Name

 AP-00000040 I*4   CHOICE        3-00000000  R*4   WS_ID       3-00000004  R*4   XMAX        3-00000008  R*4   YMAX


FUNCTIONS AND SUBROUTINES REFERENCED

  Type  Name              Type  Name

        CE_MAP                  OR_MAP
```

Appendix D Sample Mapping Software Output







Appendix E SSM/I Data Catalog

SSM/I Data Received

Tape #	Beginning of dataset	End of dataset	# files
01	01-Jun-89:00:07:31	05-Jun-89:00:57:56	56
02	05-Jun-89:00:57:56	09-Jun-89:00:06:24	20
03	09-Jun-89:00:06:24	13-Jun-89:00:56:52	55
04	13-Jun-89:00:56:53	16-Jun-89:00:18:21	42
05	16-Jun-89:00:18:21	20-Jun-89:01:08:51	49
06	20-Jun-89:01:08:51	24-Jun-89:00:17:17	54
07	24-Jun-89:00:17:18	28-Jun-89:01:07:33	49
08	28-Jun-89:01:07:33	01-Jul-89:00:28:44	42
09	01-Jul-89:00:28:55	05-Jul-89:01:18:59	49
10	05-Jul-89:01:18:58	09-Jul-89:00:27:20	53
11	09-Jul-89:00:27:20	13-Jul-89:01:17:35	54
12	13-Jul-89:01:17:35	16-Jul-89:00:38:48	42
13	16-Jul-89:00:38:40	20-Jul-89:01:29:01	57
14	20-Jul-89:01:29:01	24-Jul-89:00:37:17	12
15	24-Jul-89:00:37:17	28-Jul-89:01:27:89	32
16	28-Jul-89:01:27:29	01-Aug-89:00:35:45	56
17	01-Aug-89:00:35:45	05-Aug-89:01:25:54	57
18	05-Aug-89:01:25:54	09-Aug-89:00:34:07	51
19	09-Aug-89:00:34:07	13-Aug-89:01:24:18	57
20	13-Aug-89:01:24:19	16-Aug-89:00:45:28	42
21	16-Aug-89:00:45:28	20-Aug-89:01:35:36	56
22	20-Aug-89:01:35:36	24-Aug-89:00:43:47	53
23	24-Aug-89:00:43:47	28-Aug-89:01:33:51	57
24	28-Aug-89:01:33:51	01-Sep-89:00:41:48	56
25	01-Sep-89:00:41:46	05-Sep-89:01:31:45	55
26	05-Sep-89:01:31:45	09-Sep-89:00:39:47	56
27	09-Sep-89:00:39:47	13-Sep-89:01:29:43	57
28	13-Sep-89:01:29:43	16-Sep-89:00:50:41	42
29	16-Sep-89:00:50:41	20-Sep-89:01:40:33	57
30	20-Sep-89:01:40:33	24-Sep-89:00:48:26	56
31	24-Sep-89:00:48:26	28-Sep-89:01:38:15	57
32	28-Sep-89:01:38:15	01-Oct-89:00:59:09	40

There is no data missing from our requested set.